Power Transmission Engineering®

APRIL 2020

RESPONDING TO CRISIS

POWER TRANSMISSION SUPPLIERS NAVIGATE THE NEW NORMAL

BEARINGS MANUFACTURERS STAY OPEN FOR BUSINESS

GEAR DRIVES

AUTOMOTIVE

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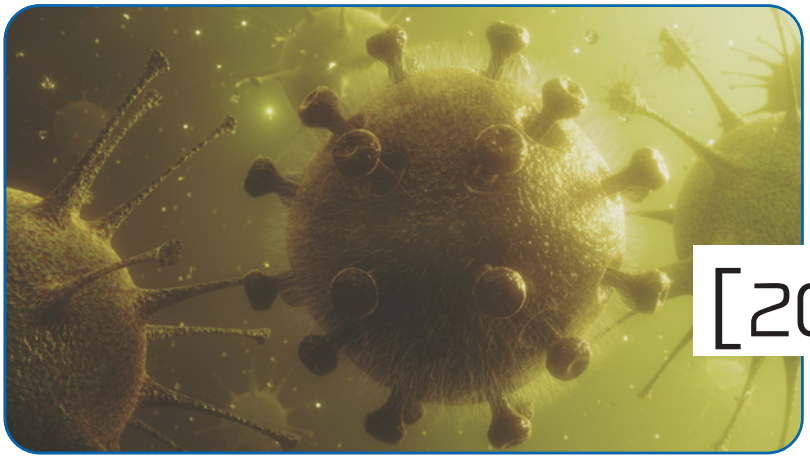

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A Publication of
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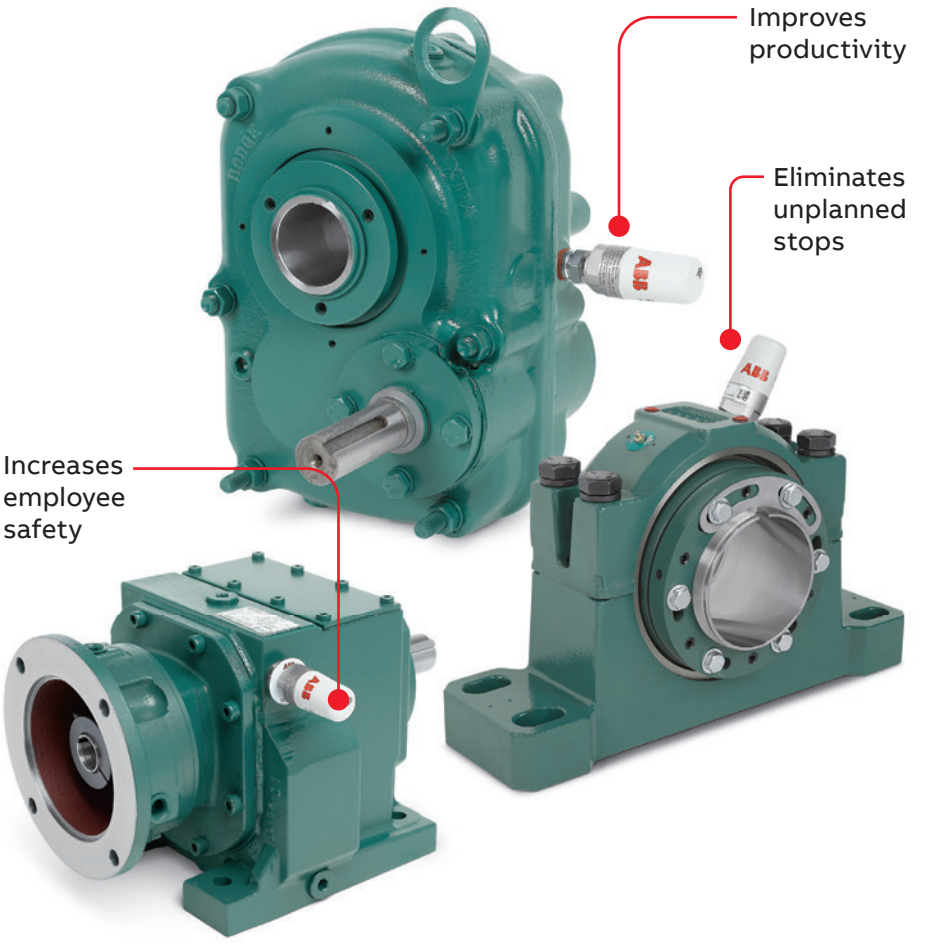

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For mechanical components

The ABB Ability™ Smart Sensor for mechanical products is an easy-to-use, wireless sensor which monitors the health of mounted bearings and gear reducers. The sensor provides warnings when health status declines, reducing the risk of unplanned downtime. In addition, connectivity and trend data allow maintenance to be planned proactively instead of reactively, and remote monitoring capabilities keep employees away from areas that are difficult or dangerous to access.

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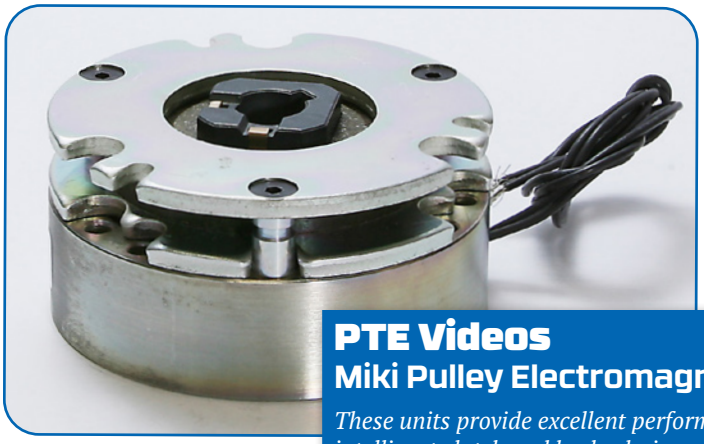


PTE Videos

Miki Pulley Electromagnetic Brakes

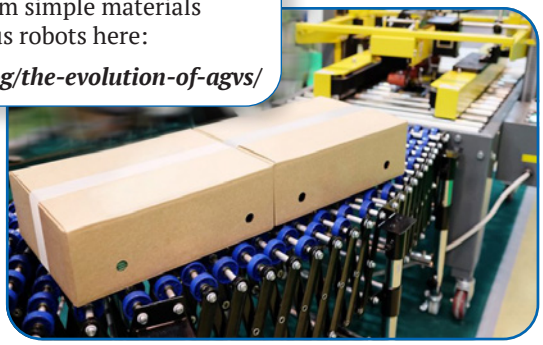
These units provide excellent performance thanks to intelligent clutch and brake designs suited to the full range of general industrial machinery. Learn more here:

www.powertransmission.com/videos/Miki-Pulley-Electromagnetic-Brakes-/

Editor's Choice

Jonathan Wilkins, marketing director of obsolete industrial parts supplier, EU Automation, discusses how automated guided vehicles have advanced from simple materials handlers to intelligent autonomous robots here:

www.powertransmission.com/blog/the-evolution-of-agvs/



Upcoming Events

Be sure to check our online event calendar to see the latest trade show news and to keep track of upcoming schedule changes.

www.powertransmission.com/events.htm

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Randy Stott
Publisher & Editor-in-Chief

Leading Through Crisis

Manufacturers are awesome.

Over the past month, we've talked to a lot of manufacturers of gears, bearings, motors, gearboxes, couplings and other mechanical power transmission components. Despite the challenges brought about by the COVID-19 pandemic and the current economic crisis, they've been universally positive and remarkably confident about their current operations and ability to continue through the crisis and after.

I'm amazed at their calm, their pragmatism and their willingness to weather the storm. I'm impressed by how smoothly they've implemented social distancing and increased workplace hygiene without missing a beat. And I'm extraordinarily grateful for their compassion, charity and willingness to pitch in wherever needed.

Manufacturers are good people.

As essential businesses, most manufacturing operations have remained open in order to meet the demands of industry. But none of them are doing so recklessly. They're mindful of the safety and health of their employees, their customers and those they come in contact with.

Sure, there are some factories that have been completely shut down, and others that have laid off workers. But we've heard of many that are increasing production or repurposing their manufacturing lines to convert to the emergency production of supplies and components for ventilators or personal protective equipment.

Nobody we spoke with is blind to the challenges, either. They're all watching their cash flow, managing their supply chains and planning to help their businesses survive over the next several months. And unlike many companies whose businesses have been devastated by the crisis – the local retailers, restaurants and other service-oriented businesses; the airlines and travel industry; the list goes on – manufacturers will survive.

In fact, they'll be the engine that powers the economy as we all struggle to emerge from what is undoubtedly a recession, even if the lagging government figures haven't revealed it yet. Manufacturers are keeping the economy going, and they'll continue to do so as the rest of the world recovers.

And it's not just the nature of their business. It's not just the fact that many of these businesses simply *can't* stop operating. After talking with so many of them over the past month and hearing their stories, it's clear to me that what sets manufacturing companies apart is also the can-do attitude of those who run them and those who work in them.

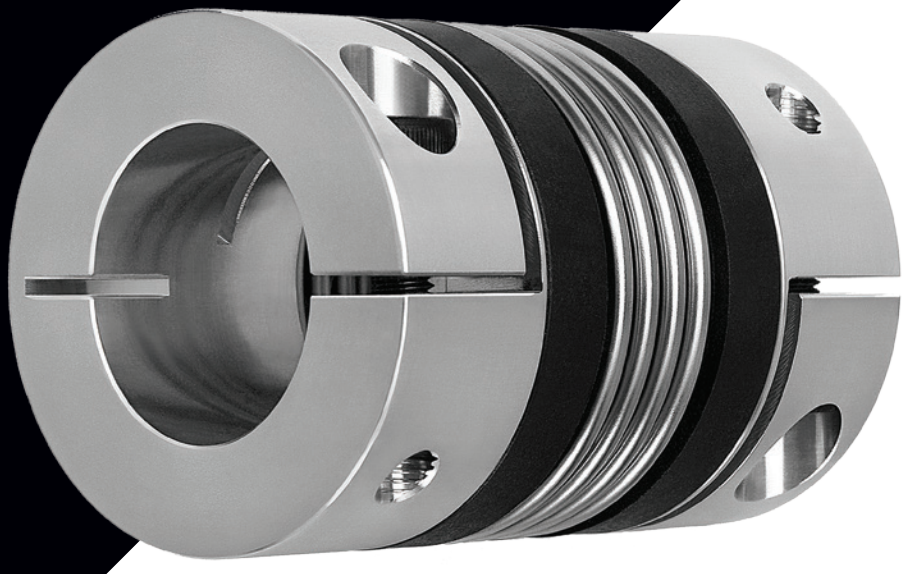
You can read more about how manufacturers of power transmission components are coping with the crisis, how they're helping other essential businesses and how they're meeting the challenges of this unique situation. We've shared some of their stories in our special coverage this issue (see pages 20-29).

Rest assured that just like the manufacturing industries we serve, we'll keep working, too. Every issue, we'll keep bringing you the most up-to-date, technically relevant information available. We don't want to miss a beat, either.

So, we'll keep delivering the information you need. You just keep being awesome.

P.S. If you find yourself working from home, now's a great time to renew your subscription. You can opt for either home delivery or our digital version (delivered by email). Renewing is fast and easy. Just go to *www.powertransmission.com/subscribe.htm*.

FOR SPEED AND ACCURACY



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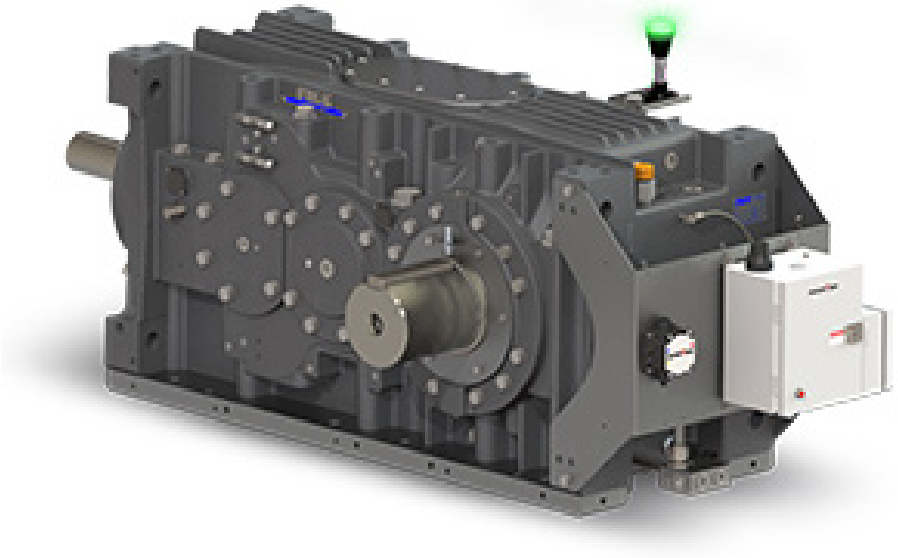

Proven maintenance savings alone enable manufacturers to recoup their investment in the Rexnord Series 1000 Smart Condition Monitoring System, powered by DiRXN, in less than a year. Additional productivity gains are driven by increased uptime and enhanced safety.

Customers can now choose from four levels of monitoring, from continuous monitoring of overall gear drive vibration and temperature, all the way up to comprehensive cloud-based notification of abnormalities. And in an industry first, the base model now comes standard on select new Falk V-Class and A-Plus Gear Drives.

These easy-to-deploy solutions make condition-based maintenance accessible on a sliding scale to match manufacturers' priorities and budgets. Customers get the right information at the right time to further extend their Rexnord products' already-premium operating life.

"This more cohesive, cost-effective approach eliminates unnecessary maintenance activities and significantly lowers total cost of ownership for mission-critical and standard gearbox assets," says Rick Morse, Rexnord vice president of innovation & digital solutions. "The new models accelerate the customer's journey from run-to-failure or schedule-based maintenance to condition-based maintenance."

The Smart Condition Monitoring System uses proprietary algorithms to continuously compare sensor data against models of healthy gear drive operating conditions. Abnormal conditions trigger alerts to onsite visual indicators, the control system, and at the highest level, the Rexnord Connect Portal.

The system puts data in context, enabling customers to focus on outcomes; teams know what action to take when and why. Manufacturers gain the ability to replace time-consuming, hands-on equipment inspections with digital technology that enhances team safety, extends asset life, and lowers inventory and operating costs.

Morse says the scalable solution addresses current and future customer needs, with hardware and instrumentation incorporating common user interfaces and industry-standard communications protocols.

"We heard from manufacturers in mining, steel, cement, and pulp & paper that they're keen to deploy condition-based maintenance solutions that can scale for different monitoring applications," he says. "The new series lets you zero in on the most immediate need, with field upgrades whenever you're ready to move from our base model to one of our more advanced solutions."

The Series 1000 Smart Condition Monitoring System offers rich features and functions to help manufacturers avoid unplanned downtime and eliminate unnecessary maintenance costs. Installation is fast and easy. Existing Falk Gear Drives can be upgraded with models 1010,1020,1050, and 1150 at a certified repair facility or your own facility, by certified Rexnord third-party technicians or by your qualified personnel with assistance from Rexnord or third-party technicians.

For more information:
Rexnord Corporation
Phone: (414) 843-3000
www.rexnord.com

Schaeffler's

TORQUESENSE OFFERS LONG-TERM STABILITY

In order to achieve maximum efficiency in industrial drivetrains and processes, it is essential to have precise knowledge of the torque and its distribution.

Schaeffler's TorqueSense torque measurement module offers a mechatronic solution that allows applications and processes to be monitored and controlled with significantly greater precision as the torque is recorded right where it is applied. The digital revolution and the linking of components and systems increase the efficiency of machines and equipment.

Schaeffler's Smart EcoSystem offers a standardized hard and software infrastructure from components equipped with sensors

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through to digital services and business models. It provides reliable data for controlling processes and machine monitoring with sensors and mechatronic products such as the TorqueSense Module. Schaeffler's unique domain expertise in the form of digital services allows the company to automatically generate relevant information from the collected data and to receive specific recommended actions. These solutions can be used in a targeted manner to control processes, maximize availability, and optimize product quality.

For more information:
Schaeffler Group USA
Phone: (803) 548-8500
www.schaeffler.us

GWJ

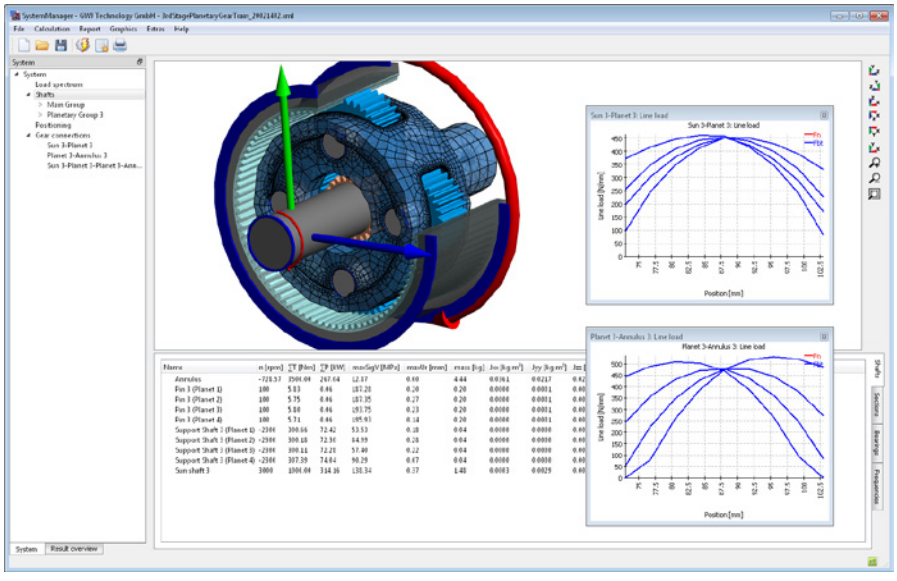
OFFERS LATEST VERSION OF SYSTEMMANAGER

The new *SystemManager* version - an extension of the standard calculation software *eAssistant* and *TBK* - allows users to create shaft geometries using background graphics. A background drawing can be added by pasting it from the clipboard, for example from a PDF document, or as an image (png, jpg, tif, bmp). Then the shaft geometry can be drawn as a polygon. Scaling of the background graphic is also possible. Alternatively, the shaft geometry can consist of several shaft segments. The mouse (left mouse button + SHIFT key) can be used to adjust the lengths and diameters of the shaft segments to the required size. The CAD import as DXF or STEP now also allows a rotation of the drawing in case the shaft axis is not the x-axis.

A new function automates the coupling of the face coefficient KHß and the load capacity calculation of cylindrical gears. This allows the user to see directly the effects of flank modifications on the root and flank safeties of the gear in the system. This is also possible when using load spectra for the calculation. The line loads of all load cases are represented in a diagram. For 3D elastic parts with elastic bearings, now contact between bearing ring and part can be considered. The fitting is then considered in the contact model instead in the operating clearance of the bearing.

It is now possible to consider centrifugal expansion on 3D elastic parts. Additional new features for 3D elastic parts are new possibilities for mesh import and mesh export. Also new faces for connection with supports can now be defined directly within the software.

The updated version also features a variety of new interface functions such as the output of diagram values to different formats, freezing of diagrams or copying of curves from one diagram to another. The bearing databases from Schaeffler (INA/FAG) and SKF are



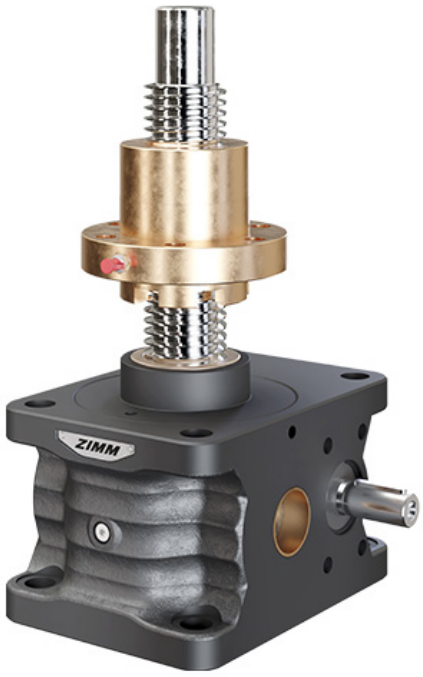
updated to latest data from the manufacturers. For data exchange of complete gear systems, the FVA´s REXS format is supported in version 1.2.

For more information:
GWJ Technology
Phone: +49 (0) 5311293990
www.gwj.de

DieQua

ANNOUNCES ZE SERIES SCREW JACK PLATFORM

DieQua Corporation has announced its new ZE Series from Zimm Screw Jack Systems with upgraded features. ZE, short for Zimm Evolution, represents the latest design features of their dynamic screw jack platform. The ZE offers increased gearbox lubrication capacity, reduced backlash, a smoother body design, and all sizes can be mounted in any position at full rated static load capacity. It is compatible with all existing Z-Series sizes and accessories.



Zimm Screw Jack Systems center around an electromechanical drive system, handling load capacities from just a few pounds to 100 tons and moving these loads, no matter what the size with precise positioning and accuracy.

For more information:
DieQua Corporation
Phone: (630) 622-2132
Diequa.com

Heidenhain

RING ENCODER RESISTS CONTAMINATION

Heidenhain introduces a new mid-range high accuracy ring encoder that is suitable for position measurement applications that require high tolerance to contamination but do not demand the accuracy level of an optical encoder. This unique Heidenhain ERM 2203 is optimized to meet those needs and is a welcome alternative to the market.

The new Heidenhain ERM 2203 ring encoders are most suitable for applications such as gear-wheel grinding machines and others that require similar high accuracy but must operate in an often-contaminated environment.

The sturdy ERM 2203 retains the 200 µm signal period as other current ERM products, though the graduation error has been reduced by

approximately 30%. Also, the interpolation error has been cut in half and reversal error has been negated as compared to other ERM encoders. All these improvements enable this ERM 2203 to be mechanically and electronically compatible to other Heidenhain ERM and can be substituted in those applications that require a higher level of performance.

It is noted that when compared to other encoder technologies in machine tool applications, the ERM 2203 is a good alternative due to its high accuracy combined with its sturdiness. And compared to other encoder products utilizing magnetic scanning technology, the ERM 2203 offers a significantly higher line count along with a lower interpolation error and generous mounting tolerances in the axial direction.

For more information:
Heidenhain Corporation
Phone: (847) 519-3988
www.heidenhain.us

Neugart

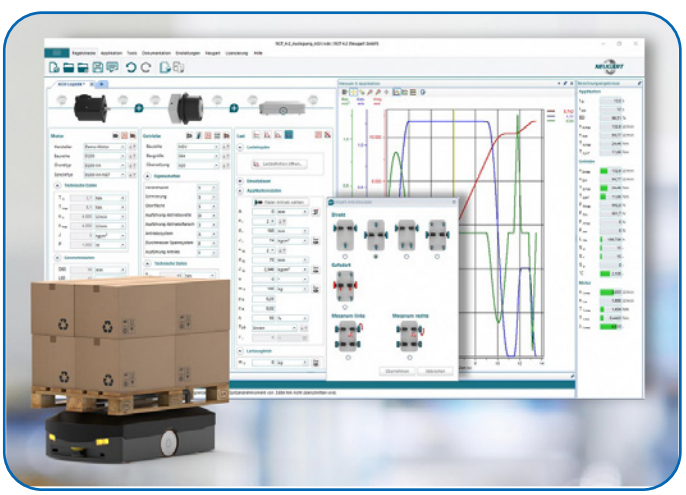
OFFERS LATEST NCP SOFTWARE UPDATE

A direct route to a cost-efficient and energy-efficient gearbox/motor combination is available with the *Neugart Calculation Program (NCP)*. The user-friendly configuration tool is now available in the new software version *NCP 4.2*. Customers of the gearbox specialist can download the free version now.

Complex load trends in the drivetrain can be calculated in the *NCP*, and the optimum application-specific motor/gearbox combination determined on this basis. With the update, it is now also possible for propulsion drives in Automated Guided Vehicles (AGVs) and the new NGV gearbox range that is tailored to these vehicles. Existing projects from current or older *NCP* versions can now also be loaded for newly designed controlled systems and compared with them.

Neugart has simplified the operation of the tool with version 4.2 and improved user friendliness: conversions are no longer required when importing read-out motor data, for example. Users of popular CAD programs can now also use the familiar full stop as a separator as well as the comma. Calculations can also be carried out in the input fields. And the gearbox documentation has also been optimized, meaning that the user detects whether the selected gearbox is suitable based on utilization bars.

For more information:
Neugart GmbH
Phone: +49 7825 847-0
www.neugart.com



Regal Beloit

OFFERS WIRELESS VIBRATION AND TEMPERATURE MONITORING

Regal Beloit Corporation recently announced the introduction of new solutions for wireless vibration and temperature monitoring. The Perceptive Technologies wireless monitoring system provides 24/7 services to help detect abnormalities in equipment before they become problematic.

At a fraction of the cost of a wired system, this new Regal Perceptive Technologies wireless monitoring system eliminates the need to be near operating equipment and is adaptable to any industry. Monitoring can be performed on-site or from a cloud platform on equipment like fans, pumps, motors and blowers.

Regal's wireless monitoring system allows users to take advantage of the extensive industrial experience of the Perceptive Technologies team to monitor and analyze machinery remotely, helping to improve reliability and maximize production.

"Unlike other wireless systems that provide only basic diagnostic data, the Perceptive Technologies wireless monitoring system delivers complete raw and analyzed data to help manage assets and provide flexibility," said Daniel Phillips, director, reliability and maintenance—CMRP for Regal. "Users receive easy-to-understand, actionable information without the need for manual diagnosis."

For more information:
Regal Beloit Corporation
Phone: (630) 364-8800
www.regalbeloit.com

Klingelnberg

OFFERS LATEST METROLOGY SOLUTIONS

Here's an overview of some measuring machines for bearings and large gears from Klingelnberg:

P 16 G – Solutions for complete measurements of roller bearings

Roller bearings have to perform several different tasks at once: they have to ensure high stability for shafts while providing low power losses and high durability. The resulting requirements concerning material, geometry, form accuracy and surface roughness represent a particular challenge for manufacturing, as current quality standards require the use of a number of different precision measuring devices. Dimensions are therefore measured on a coordinate measuring machine, form and noise emission on a form tester, surface roughness on a surface tester and contours (e.g. edge radius) on a contour measuring station.

P 100 – Innovative measurement solutions for large components

Whether making gearings for rail transport, the wind power industry, printing machines or the mining industry — the fully automatic CNC-controlled P 100 precision measuring center is the perfect fit. Highly precise, reliable and compact, and available with the whole range of software and hardware options, this precision measuring center ensures that all universal requirements will be met, even for job shoppers. Long workpieces can easily be clamped between centers and reliably measured thanks to a long vertical axis measuring up to 1200 mm. The high-precision rotary table allows the P 100 to be used as a full-fledged form measurement device.

Please contact Klingelnberg directly to discuss the company's services and software solutions.

For more information:
Klingelnberg America, Inc.
Phone: (734) 470-6278
Klingelnberg.com

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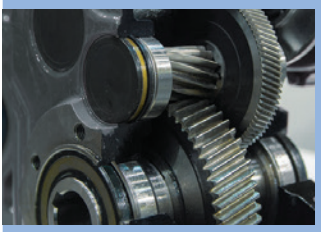

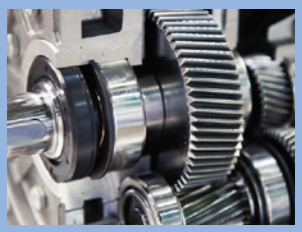
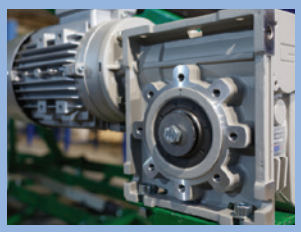
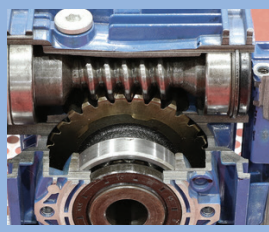

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Products include...

SYN LUBE SERIES 150 - 1000

High performance, fully compatible PAO-based gear oils.

SYN LUBE HD SERIES

Heavy-duty, (EP) extreme pressure, PAO-based gear oils.

SYNTHETIC WORM GEAR LUBRICANT

High performance, ISO 460 Grade, PAO-based worm gear oil.

PGO SERIES

Ultra high-performance, PAG-based gear oils.

PGO-FGL SERIES

NSF H1 registered, food machinery grade, PAG-based gear oils.

SFGO ULTRA SERIES 150 - 1000

NSF H1 registered, food machinery grade, PAO-based gear oils.

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Dynamic Performance

PTE Examines Gearmotor and Gear Drive Technology

Matthew Jaster, Senior Editor

The following is a compilation of product highlights for gear drives and gear motors. Some are new, some are old, but they all offer significant performance advantages in areas like construction, packaging, food and beverage, robotics, automation and more.

Hub City SS HERA gear drives provide twice the output torque capacity of standard worm speed reducers.

Regal Beloit

OFFERS HUB CITY HERA GEAR DRIVES

Hub City stainless steel (SS) HERA gear drives are rated IP69K, built for sanitary operation, and have easy cleanability and polished stainless-steel housings. SS HERA gear drives are 90% efficient—up to 40% more efficient than standard worm gearing—and each size is dimensionally interchangeable, for up to four sizes of worm drives for inventory consolidation and reduction. Now, with the addition of two larger stainless-steel models, the SSHERA55 and SSHERA75 (with torque capacity up to 8,500 in-lb), the four models in this product suite can replace up to 12 sizes of worm speed reducers. In addition to the dual lip seals specifically configured for severe high-pressure, high-temperature and chemical washdown requirements, HERA gear drives are HACCP compatible, BISSC certified and USDA accepted.

Because these gear drives use helical and hypoid gear technologies, not only do they provide up to twice the output torque capacity of standard comparable worm speed reducers, they are also a viable and economical replacement for other types of right-angle gear technologies in the marketplace, such as helical-worm or helical-bevel gear drives. Helical-hypoid gearing lasts longer than worm gearing due to cooler operating temperatures and rolling action (instead of sliding friction) can provide longer gearbox life and reduced downtime in time-critical industry applications.

The Hub City SS HERA gear drive product suite also features a new split stainless-steel output cover for the HUBLOC keyless bushing system. This bolt-on cover design features a smooth profile and provides knockouts for shaft extensions. The HUBLOC keyless bushing system provides a positive fret-free connection to driven equipment that is easy to install and remove.

The Hub City SS HERA gear drive is part of a suite of IP69K-rated products from Regal.

For more information:
Regal Beloit Corporation
Phone: (630) 364-8800
regalbeloit.com/IP69K.

Atlanta Drive Systems

OFFERS RACK AND PINION, LINEAR ACTUATOR AND SMART TECHNOLOGIES

Rack & Pinion Drive Systems

Atlanta Drive Systems offers a complete range of standard rack and pinion drive systems, which are available in five levels of precision, including ultra-high precision zero backlash axis drives. They are perfect for a wide range of applications, including axis drives requiring precise positioning and repeatability, traveling gantries and columns, pick and place robots, CNC routers and material handling systems. Heavy loads and duty cycles can also be easily handled with these drives. Industries served include material handling, automation, aerospace, woodworking, machine tool and robotics.

This range of drive systems utilizes Atlanta's wide range of rack and pinions, consisting of both helical and straight (spur) tooth versions, in an assortment of sizes, materials and quality levels. Rack quality levels include soft, induction-hardened, quenched and tempered and hardened and ground (DIN 3 to DIN 10, AGMA 8 to 12+).

Typical delivery time for these systems is only 2 to 3 weeks-ideal for OEM's requiring just-in-time delivery schedules. Special and/or modified designs are always possible.

Industry 4.0 Developments

Atlanta is integrating Industry 4.0 into its rack and pinion and servo reducer products. All racks are measured for pitch deviation, individually marked and logged in the cloud. Using an app, customers can scan a rack and look up the production and product information. It would be possible to order an exact replacement of the rack with the same tolerances.

Customers can use this information to optimally mount racks to achieve an overall pitch deviation near zero. The customer can scan a series of racks and then the app would tell them in what order to mount them to achieve zero pitch error.

For gearboxes, the motor flanges are fitted with sensors to measure temperature, vibration, speed and displacement. This helps monitor the gearbox and motor to insure they are working properly.

For more information:
Atlanta Drive Systems
Phone: (800) 505-1715
www.atlantadrives.com

Bonfiglioli

IMPROVES PERFORMANCE AND EFFICIENCY IN EXCAVATOR AND AGV APPLICATIONS

Bonfiglioli offers a complete drive solution for 2–3 ton mini-excavators. This fully electric alternative to the conventional axial piston hydraulic unit reduces noise levels and CO_2 emissions.

The complete electric powertrain dramatically improves the efficiency of the machine and extends the maintenance interval providing a significant reduction of the total cost of ownership. While the gear units benefit from over 65 years of experience by Bonfiglioli in the field of conventional hydraulic applications, the electric motors have been specifically designed and developed to match the demanding requirements of the market in terms of energy efficiency, compact dimensions and high power density.

In the area of Automated Guided Vehicles (AGVs), Bonfiglioli gearboxes meet the necessary requirements.

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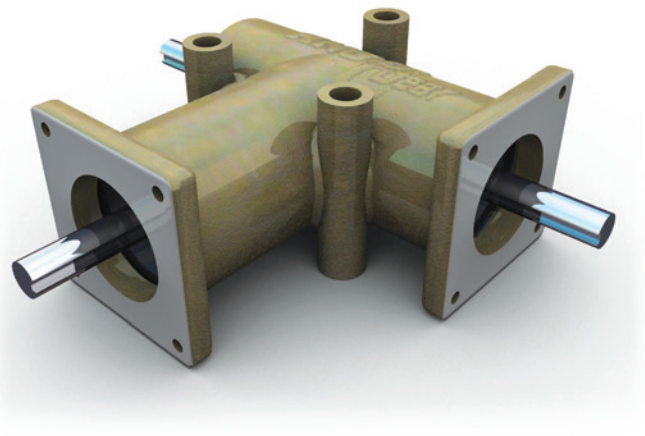
Andantex USA's objective over the years has always remained the same: to provide innovative, high-quality gearboxes and solutions for use on industrial machinery.

The Anglgear® right angle drive is an example of our commitment to our customers' needs and applications. The Anglgear has grown into a product that is now used in various applications across the printing, converting, packaging, general purpose and aerospace industries.



In addition, we also supply all branches of the military, conforming to contracts specifying various MIL SPEC requirements.

The Anglgear line consists of 14 different models available from stock in both an Inch and Metric series and sold worldwide.

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Examples of our modifications include various shaft lengths and configurations, including shafts with flats, splines, holes, etc. We also offer 3-way units with counter-rotating output shafts, as well as custom housings with flanges and bosses removed for custom mounting applications. Special materials, bearings, seals and epoxy coatings as needed. We can provide units with special backlash upon request, and offer various options for grease including food grade, high temperature and radiation resistant.

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Navigating the New Normal

Leadership Discusses COVID-19 Threat in PT Industry

Editorial Team, PTE Magazine

To say the last month has been unusual would be the understatement of the year. Here we are, working from home offices, making conference calls by video chat, and trying to establish some sense of normalcy during a time that is anything *but* normal.

The editors of *PTE* have compiled the latest information from power transmission component suppliers regarding the COVID-19 pandemic. Some stories are about working on the frontlines to fight the disease, others are simply how organizations are building essential components under new, challenging work environments. Each story is unique, preparing all of us for the many obstacles and difficulties to come in the months ahead.

A Change in Routine

Carl Rapp, president, Philadelphia Gear, vice president, power systems group, The Timken Company, discussed the many new challenges manufacturers are facing in 2020.

"Shifting to the new norm of social distancing and working from home for those who can. Fortunately, our business networks are reliable, and our people are adapting quickly, so other than occasional bandwidth issue, our teams have done a good job making the change and we haven't had any substantive disruptions to office workflows," Rapp said.

Rapp also discussed the importance of providing real-time solutions during global disruptions like COVID-19.

"Our business systems and machine tools are well-built and well-maintained, but I think right now for all of us, it's really about making sure the basics are being delivered. No one is really doing any successful pro-active selling right now anywhere. No customers are listening to those messages in this new norm. Instead we're trying to prioritize resources and meet the most urgent demand for our most important end-users, in a timely fashion," he said.

Philadelphia Gear has recently provided emergency repairs on gearboxes, motors and generators to help other critical infrastructure companies function.

"Last week we sent a field service engineer to troubleshoot a job when others wouldn't or couldn't go. We are also deeply involved in the defense industry and have clear directives relative to the need to maintain our schedules to serve the warfighter. We are open to helping in any way we can to manufacture parts or provide repair services for the electromechanical systems that power the world, and which allow millions of citizens to remain safely at home," Rapp said.

As a provider of 'essential services' as defined by Homeland Security and DoD, Philadelphia Gear's manufacturing and service centers are open to serve the critical infrastructure of the nation's power plants, refineries, water/waste management, defense and other sectors.

"A huge number of our team members are home, continuing their daily routines via WebEx, conference calls and

While increasing safety measures at its plants and warehouses, NSK continues to meet a steady demand for shipments to its authorized distributor network (see sidebar on page 27).

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social media platforms to serve customers. We are adapting and in doing so providing some level of economic continuity," Rapp said.

For Maxon Motors, the supply chain remains a critical obstacle.

"The biggest challenge for the company is the supply of materials. The gaps in the supply chain are increasing and the situation is expected to deteriorate further," said Eugen Elmiger, CEO Maxon Group. "Through a short time working program at our headquarters in Switzerland and a global cost savings program, we will ensure operational reliability over the coming months. Until further notice we will continue production five days a week."

The Altra Industrial Motion Supply Chain Team is proactively working with its suppliers to keep current and manage the evolving needs of their customers. In many cases, they have multiple suppliers for critical components and materials, redundant manufacturing capacity in many of their businesses and strong relationships with suppliers that they will leverage where possible.

Currently, these proactive steps are working. However, as the situation evolves, the Altra Supply Chain Team recognizes there may be additional steps needed and they will continue to proactively communicate with customers. The senior leadership team remains vigilant and is monitoring the situation in real time and responding rapidly as conditions evolve. (*Editor's Note: Read about Boston Gear and Bauer Gearmotors direct response to fighting COVID-19 in the next sub-section*).

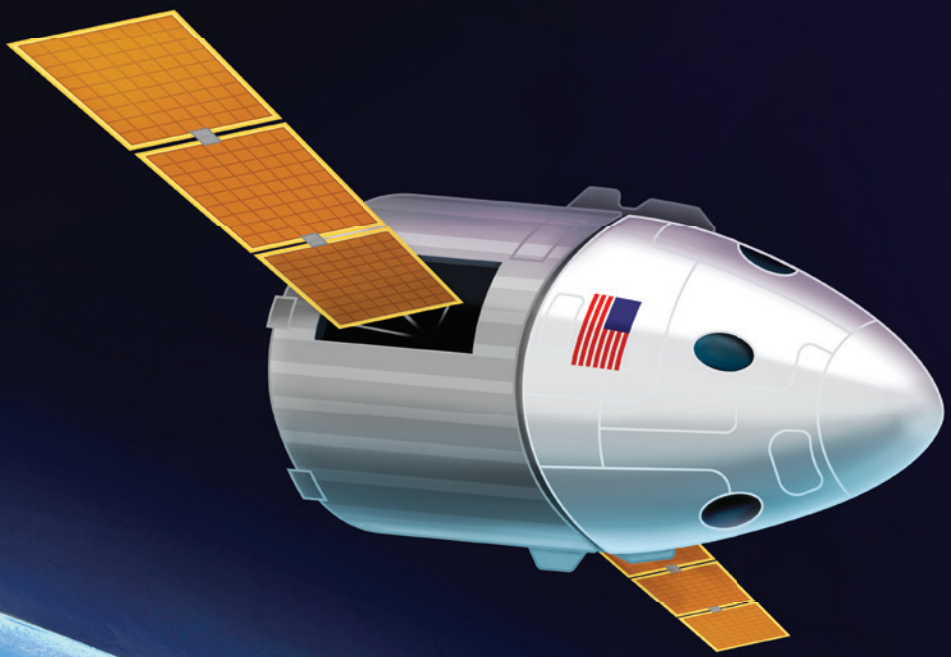
Though Gear Motions does not provide end products to the market, it is a vital link in the supply chain supporting those companies essential to meet the needs in this crisis.

H2W Technologies manufactures voice coil actuators for medical applications.

Gear Motions supplies product used in medical equipment, food processing, power generation, transportation, aerospace/defense, and construction. Without the products produced by Gear Motions, these essential businesses cannot meet their needs during this crisis.

"We take the health and safety of our employees as our highest priority and have instituted new measures to assure their protection while within the facility. We have taken steps to prohibit visitors, implemented social distancing, and increased attention to cleaning and disinfecting at the facilities. We have shifted all non-essential office personnel to remote work and are adjusting staffing to balance shift sizes. We continue to monitor directives from the CDC, and we will continue to comply with the guidance and directives for maintaining a clean and safe work environment issued

WEG recently announced an agreement with LEISTUNG to produce artificial ventilators that will be used by patients tested positive for COVID-19.



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by the Department of Health," said Dean Burrows, president and CEO at Gear Motions.

Facing the serious global COVID-19 situation, NSK Americas continues to place the highest priority on the health and safety of its employees, customers and suppliers while working intensely to ensure business and supply continuity for its customers.

Brian Parsons, CEO, NSK Americas and vice president of NSK Ltd. states: "As a critical infrastructure supplier to many key industries, NSK is focused on keeping its employees safe and healthy, and maintaining full support to its customers."

Fighting on the Frontlines

The following companies are providing resources, components and materials directly in the global fight against COVID-19:

Mechanical Power Transmission Components

"Our teams across the globe are also helping our customers and partners maximize our existing digital services to keep critical services running safely, and we are finding new virtual ways of connecting with each other and our stakeholders," said Bjorn Rosengren, CEO of ABB. "To further support our customers, we have decided to make some of our software services available free to ensure uninterrupted power supplies to critical healthcare applications and to support commercial and industrial facilities in better managing their facilities."

ABB has donated masks and delivered protective equipment to hospitals and frontline workers in some of the most badly affected countries, such as China and Italy. The company is currently working with governments to assess where ABB could use its technology and expertise to support the production of critical equipment, such as ventilators and masks.

WEG recently announced the signature of a technology transfer agreement with LEISTUNG Equipamentos Ltda., a manufacturer of medical equipment, to produce artificial ventilators that will be used by patients tested positive for COVID-19.

The contract, signed between the companies, grants WEG the license to produce the ventilator based on the mechanical ventilation device "Luft-3" from LEISTUNG.

WEG will use the current structure of its factories in Jaraguá do Sul, in the state of Santa Catarina, to produce ventilators and works with the possibility of adjusting the project to speed up production.

The plan is to immediately purchase all required components in order to produce 500 ventilators. Once the production line is installed by WEG, they will have an estimated capacity to produce 50 ventilators per day and deliver in the second half of May.

"We now depend on obtaining electronic and pneumatic components, many of which are imported and are currently in short supply in the market," says Manfred Peter Johann, managing director of WEG Automation.

The implementation of the production line will follow all heath hygiene protocols and other protective measures recommended by health authorities for industries.

Bearings manufacturing has continued throughout the crisis at Napoleon Engineering Services.

Boston Gear and Bauer Gearmotor are providing mechanical overload clutches and worm gears for sanitary products, COVID-19 test kits and respirators. The greatest challenges the company is currently facing includes getting material from vendors and managing staffing during the shutdown.

"We're enforcing new social distancing policies at our facility," said Michael Stegmann, product manager at Altra Industrial Motion. "We have self-manufactured masks to supplement what we could purchase from mask suppliers."

He added that one of the keys to maintaining business during a time like this is simply, "Communication, Communication, Communication!"

Andantex management has taken precautions to ensure the safety of all employees. They have gone to split shifts in all departments and on the days that are not in the office, they are able to work from home. They have a maximum of 10 people inside the entire facility at any one time. However, they are still making every effort to support customers by shipping open orders, maintaining availability of application assistance and providing emergency repairs as required.

Andantex USA services many customers in the critical industries of defense, aerospace, distribution supply chain, machine tools, and automation. "We have been able to ensure customers in these industries that we will be there for them and help to keep their machinery operational," says David Regiec, VP Engineering.

Located in Ocean Township, NJ, Andantex is also

supporting their local medical community. "We have provided food for lunches at Jersey Shore Medical Center in support of doctors, nurses and all health workers on the front lines trying to keep us all safe," Regiec says.

Finally, Andantex is investigating the possibility of manufacturing small steel or aluminum components that can help with shortages of medical equipment.

Marcelo A. Marcos, president of KTR Corporation, says that KTR is also open for business and ready to supply couplings for whatever industry is in need. "We manufacture a wide range of small precision couplings that can be used in some medical devices…for pump drives and for motion control," Marcos says.

Marcos adds that the KTR factory is still open two shifts. "Minor changes were made to reduce human interaction. Sales employees are working from home whenever possible," he says."

But even outside manufacturing, KTR, located in Michigan City, IN, is trying to do their part to help. "We have obtained face masks and have offered them to employees and families, as well as to local senior citizen homes and smaller clinics in the area."

Motion Control Contributions

H2W Technologies have been manufacturing voice coils that have been custom designed for the medical industry. Voice Coil Actuators in quantities of 100 to 200 are available in 4 weeks and OEM (Original Equipment Manufacturers) quan-

tities can be available in 6 to 8 weeks from receipt of order. Voice coils have been desirable for applications such as ventilators because of their compact design and high-speed capabilities coupled with their sliding contact bearing system, which allows for high lifetime, high cycle, and a desirable MTBF in the system.

In dealing with the COVID-19 pandemic many companies have volunteered or been requested to produce urgently needed medical products such as: Masks, gowns, and ventilators. "Tooling Up" quickly to produce medical grade products for some companies can bring challenges. In addition to needing FDA compliant materials that will be used in the actual masks, gowns, and ventilators, the tooling used to manufacture these products may also need to meet FDA compliance standards. Depending on the product being manufactured, the tooling may need to be: Washed down using caustic chemicals, cleaned with high pressure steam, or sterilized with high Intensity ultra-violet light or radiation.

LM76 manufactures several types of FDA compliant linear bearings and pillow blocks that are drop-in-replacements for existing bearings. FDA compliant bearings and pillow blocks from LM76 will not trap contaminating debris and can be thoroughly sanitized following Sanitation Standard Operating Procedures (SSOPs). SSOPs are detailed schedules and procedures specifying what to clean, how to clean, how often to clean, and the record keeping used for monitoring.

Bosch Rexroth said in a public statement that it is available to help companies right now that must rapidly move from prototype to full production or ramp up existing assembly operations to meet extremely urgent needs.

Bosch Rexroth offers linear motion, automation and assembly technology that can be used to build new, in-demand machines or systems, as well as modular, easy-to-assemble workstations and powered conveyor systems that are ready to integrate into production operations. Applications include: aluminum structural framing to help with medical equipment assembly and ventilator hoods; workstations, carts and flow racks for manual assembly production lines; modular conveyor systems to link work cells; linear motion technology such as stainless steel miniature ball rails and ball screws for lab and diagnostic machines; and complete Cartesian motion systems for automated fluid handling systems.

A Critical Period in Time

The major consensus from everyone we've spoken with this week is that the decisions and strategies put in place today will play a huge role in how manufacturing will look in the future. Many individuals are looking more into emerging technologies such as robotics, automation, IIoT and additive manufacturing to better prepare for crisis management in the coming years.

Everyone is being proactive and putting their employees and families first.

"With many critical services and industries at risk of being overwhelmed or shut down, we all need to work together – governments, business and civil society – to keep our healthcare systems, power networks and other essential services operational. The health and wellbeing of all of us – workers, families, society and future generations – depend on it," added ABB's Rosengren.

And we'll end with some of the best advice we heard during our interviews and discussions of this crisis:

"Tell the truth. Listen. Don't panic. Manage cash. Be there for your people, to the best of your ability," said Rapp at Philadelphia Gear. "There is a lot stress in the world right now. But as we come together and deal with this crisis, I am optimistic that we will get through this." **PTE**

For more information:

ABB
www.abb.com

Altra Industrial Motion
www.altramotion.com

Andantex
Andantex.com

Bosch Rexroth
www.boschrexroth-us.com

Gear Motions
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H2W Technologies
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Open for Business

Bearings Manufacturers Support Essential Manufacturing by Staying Open through the COVID-19 Pandemic

Randy Stott, Publisher & Editor-in-Chief

Most manufacturing enterprises are considered essential businesses and therefore have remained open during the pandemic-related stay-at-home orders. Despite difficult economic conditions, most of those we talked to have indicated that they remain positive, busy and committed to helping wherever they can.

"We have not missed a beat," says Chris Napoleon, president of Napoleon Engineering Services. "As a manufacturer of bearings in direct support of U.S. National Defense we are committed to delivering as expected regardless of the circumstances. We are producing today the same as yesterday, last month and last year and we hope the future holds the same."

Michael Stofferahn, senior vice president, Industrial Business Americas for NSK Americas, Inc., echoes those thoughts: "To date, the pandemic has had little to no impact on NSK's ability to deliver bearings. We addressed some initial component replenishment issues in our supply chain some weeks ago, but they had no real effect with regard to supplying customers.

"Our planning horizons for production and delivery are notably far-sighted," Stofferahn says, "We carry significant inventories in local NSK warehouses and the warehouses of our authorized distributor network throughout North America. That said, we are in a position to quickly modify the production requirements placed on our manufacturing facilities, including our principal global-supplying plants, as they contend with impacts of the pandemic."

Peer Bearing is also definitely still open for business. "It has not affected our ability to deliver bearings," says Steve Tomlinson, business development manager. "We are open and continue to ship product to all our OEM and Distributor customers who continue producing."

In a public statement, Timken President and CEO Richard G. Kyle said, "We continue to operate our business around the globe, leveraging our manufacturing footprint and staying responsive to demand. We are coordinating

closely with customers, suppliers and logistic partners to uphold a reliable supply of product and expertise."

So the bearing manufacturers are all open for business, all committed to providing the product their customers need. But the questions remain: How has the pandemic affected demand for their business?

At Napoleon Engineering Services, which has a strong customer base in aerospace and defense, the picture remains positive. "We believe that government (defense) sales will remain strong as the warfighter does not sleep," Napoleon says. "The commercial space market will also continue to thrive as the push for better communications and internet service intensifies. Particularly as everyone is more reliant on its use for interaction between people. Satellite system development will not decline nor will the need for launch services for deployment."

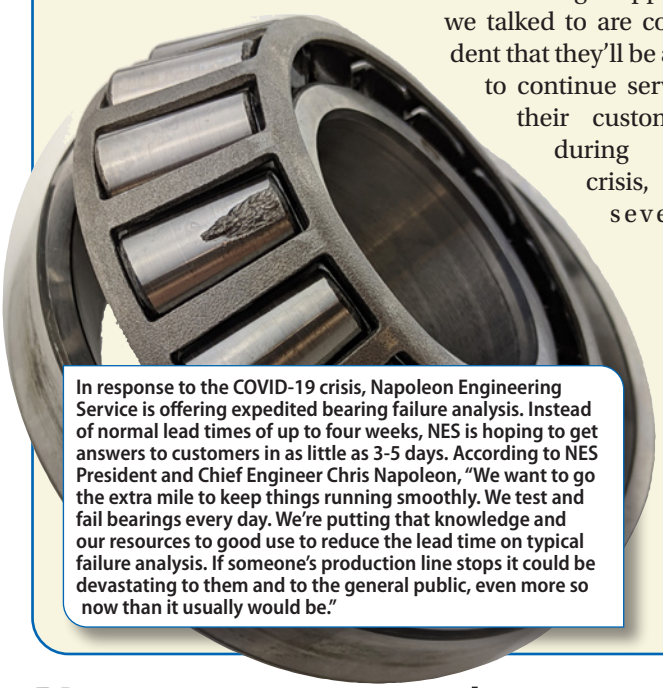
At NSK, the answer seems to be: so far, so good. "From our perspective there is no clear trend specific to any industry canceling or delaying orders," Stofferahn says. "We have the benefit of having highly fluid and responsive relationships with our aftermarket partners (distributors) and OEM customers. We're not wearing blinders though. If there is a deceleration, NSK is committed to managing it effectively, and in a manner that puts us in a strong position to seize opportunity when we've all turned the corner on COVID-19."

Others are seeing some softening of demand, especially in industries that are heavily impacted by the pandemic.

"Demand is down month over month as some customers have suspended manufacturing operations," says Tomlinson at Peer Bearing, adding that some of the harder hit areas among their customer base include agriculture, off-highway and power sports.

But it's not all bad news. In other areas, demand is solid, especially bearings for material handling conveyors and industrial gearboxes, Tomlinson says.

All of the bearings suppliers we talked to are confident that they'll be able to continue serving their customers during the crisis, but several acknowledged that there could still be hiccups in the supply chain, especially in industries like medical where demand has suddenly ramped up.



In response to the COVID-19 crisis, Napoleon Engineering Service is offering expedited bearing failure analysis. Instead of normal lead times of up to four weeks, NES is hoping to get answers to customers in as little as 3-5 days. According to NES President and Chief Engineer Chris Napoleon, "We want to go the extra mile to keep things running smoothly. We test and fail bearings every day. We're putting that knowledge and our resources to good use to reduce the lead time on typical failure analysis. If someone's production line stops it could be devastating to them and to the general public, even more so now than it usually would be."

During a crisis is no time to get lax with suppliers, they say. If you're thinking of switching suppliers, or if you need to, be careful.

"I don't think there will be a supply issue," Napoleon says. "But if there is, the actions taken have not changed unless you are willing to accept risk of product failure. Bearing qualification programs are necessary when changing suppliers; always. Bearings are not a commodity in the global supply chain. Inspection and testing is just as important and necessary as it always has been. The advice is simply, remain calm and ensure you have open and honest communications with your approved bearing supplier."

Some manufacturers may be inclined to try to save money and make buying decisions they normally wouldn't consider, but this is not the time to change suppliers, NSK's Stofferahn says. "In fact, it may be the very worst time. Be absolutely certain: counterfeit bearings remain an ongoing, onerous threat – less to legitimate bearing manufacturers like NSK, but far more to manufacturers and end-users. A single bearing failure, due to cheap materials and construction, can result in catastrophic and even injurious outcomes. That will likely cost far more than any short-term savings through questionable bearing sourcing. Our advice is to continue buying from reputable manufacturers – and their authorized distributors – to ensure full value and performance."

Of course, while all the bearings suppliers are committed to continue serving their customers, they're doing so with a mind toward the safety and well-being of their employees, customers and contacts.

"We have an incredible responsibility to maintain our health and wellbeing and are taking extraordinary steps to prolong the length of time before we are impacted by the virus," Napoleon says. "To that end, we have changed a lot of standard protocols for cleaning, interacting with others and we are spreading our workforce out across multiple shifts and working from home when possible."

NSK has a similar attitude. "Safety has always been a key focus for NSK and, as a manufacturer of precision products, our operations have been engineered with stringent quality, safety and sanitation protocols," says Stofferahn. "However, with new state and local guidelines related to the COVID-19 outbreak, we've recently modified daily activities to further ensure the health and safety of our plant and warehouse staff. This encompasses screening for all people entering NSK facilities, additional cleaning and sterilization measures, widespread distribution of sanitization products, and mandatory social distancing across all facilities, including production and rest areas."

"In addition to our strong internal standards for safety, health and business conduct, we are implementing rules and guidance from government and health authorities everywhere we operate, said Timken's Kyle. "We have taken

preventative measures outlined by the WHO and Centers for Disease Control and Prevention (CDC) that include social-distancing practices and remote working across all our locations, suspending non-essential business travel and visitor access, and ensuring frequent and deep cleaning at our facilities to maintain a healthy environment."

As a group, bearings manufacturers have definitely answered the call. They remain open for business, working through the difficulties associated with social distancing and stay-at-home orders, and most importantly, willing to help to ensure that vital industries have the components they need. Nearly all the suppliers we talked to are either involved directly in supplying components to support the ramp-up of manufacturing of ventilators, personal protective equipment or other vital medical supplies.

"Many of the manufacturers redirecting their facilities and resources to medical equipment will rely on NSK for high-precision bearings and linear motion components," Stofferahn says. "The very best thing we can do is to make sure those companies are continually supplied with the highest quality products. We've reached out to some and have a standing offer to any medical equipment manufacturer, as well as those manufacturers turning their production capabilities towards essential and critical medical supplies, to help in any way we can."

"For our medical device customer base, we continue to meet their bearing demand with inventory," says Peer Bearing's Tomlinson.

It's hard to predict how long the COVID-19 crisis will last. But one thing is for sure: manufacturers are doing their part to keep the economy moving, to support first responders and to ensure that economic recovery will not only be possible, but swift. Bearings manufacturers are a big part of that.

"I'm frankly encouraged by the collective response of industry to the current crisis," Stofferahn says. "I'm profoundly impressed and proud of our employees, our customers, and our industry. I see a universal spirit to do whatever needs to be done to overcome this pandemic, and I have no doubt that we'll continue to meet that challenge and make a positive difference." **PTE**

For more information:

Napoleon Engineering Services
www.nesbearings.com

NSK Americas Inc.
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Romax

Improves Reckon Drive Product Reliability with Drivetrain Structural Simulation Software

Kristian Kouumdjieff, Product Manager, Romax Technology

The shift towards electric drivetrains has created unprecedented demand for new transmission architectures across numerous vehicle platforms at a time when subject matter expertise is at a premium. When developing new transmission designs, meeting durability targets is almost always the number one priority. However, it is, naturally, not the only important performance attribute that must be met. Durability requirements must be balanced with the need for lightweight and low-cost solutions which meet noise and vibration targets whilst also exhibiting excellent efficiency.

The Ultimate series from Reckon are used in highly dynamic applications. Product recommendation requires safe application engineering and is performed using Romax.

Predicting Product Behavior

Reckon Drives, headquartered in St. Etienne, France, designs and manufactures helical and spur servo-grade planetary gearboxes for various kinds of applications, for laser cutting, packaging, printing machines or machine tools.

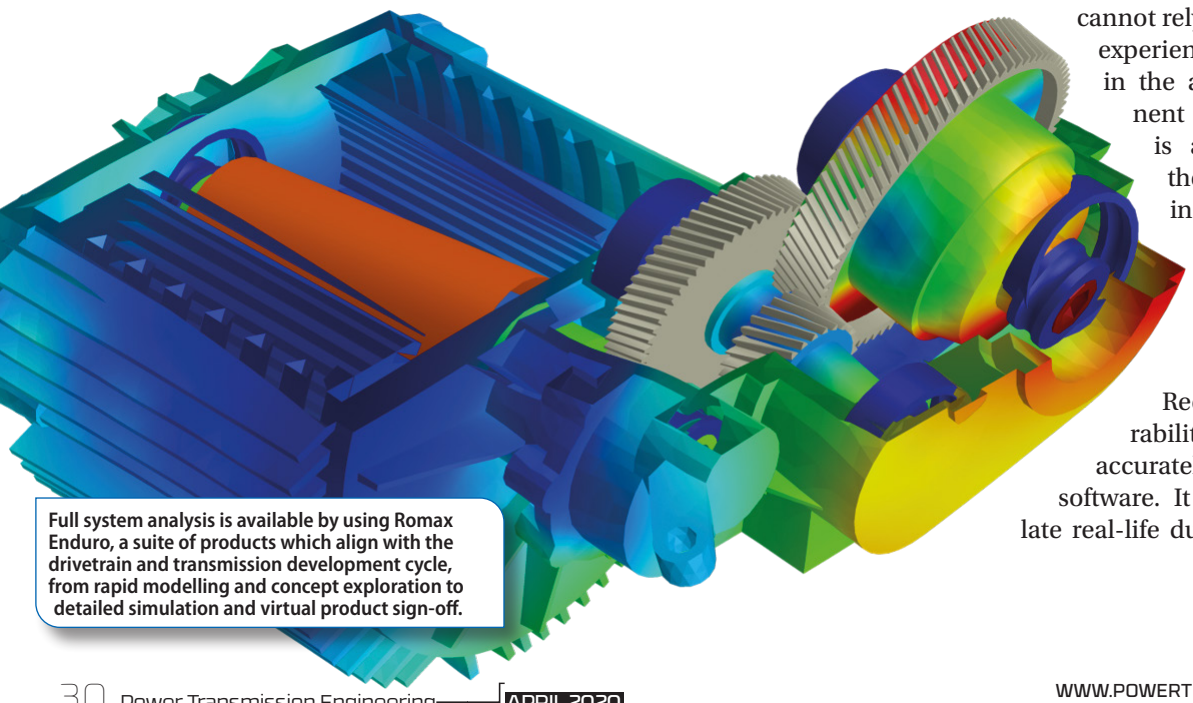
Previously, it has been difficult for Reckon to show their customers precisely how their products will behave in each application. However, predicting this is crucial for building confidence in the robustness of a design.

For many years, Romax Technology, headquartered in Nottingham in the U.K., has delivered CAE tools which enable simulation-led design. Building on *RomaxDesigner*, *Romax Enduro* is a new tool aimed primarily at drivetrain durability engineers. It is a sophisticated, yet easy-to-use structural design, analysis and optimization solution for the development of Right First Time, durable electro-mechanical drivetrain systems.

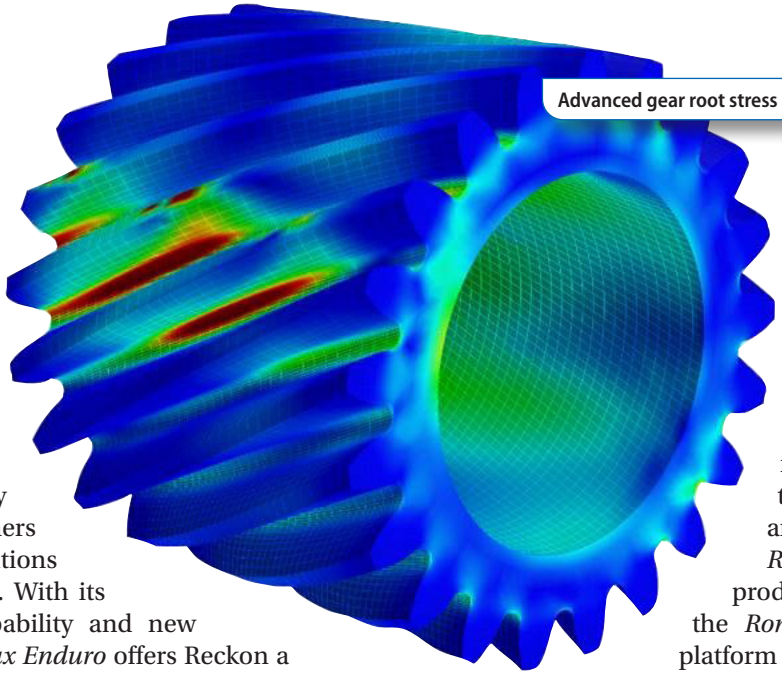
Romax Enduro allows users to understand the interactions between components in the system by incorporating advanced component contact models within a whole system structural analysis, predicting loads and misalignments and component stresses and life within a single tool. It gives insight into the behavior of the system, meaning that if a component fails then the root cause can be easily identified, and remedial design changes can be developed and tested in a virtual environment.

This is particularly important for new drivetrain architectures and applications — designers cannot rely on prior knowledge or experience to give confidence in the architecture or component sizing. Where weight is a concern and where there is flexibility of housings, shafts and carriers, *Romax Enduro* can give the required level of modelling detail and results' accuracy.

Using *Romax Enduro*, Reckon can predict the durability of their products more accurately than with any other software. It allows them to simulate real-life duty cycles and optimize



Full system analysis is available by using Romax Enduro, a suite of products which align with the drivetrain and transmission development cycle, from rapid modelling and concept exploration to detailed simulation and virtual product sign-off.



Advanced gear root stress analysis in Romax Enduro.

gearbox designs, giving Reckon confidence in the suitability of their product for a specific customer application. It enables them to quickly and clearly demonstrate to their customers the benefits of Reckon solutions over competitors' products. With its full-system simulation capability and new easy-to-use interface, *Romax Enduro* offers Reckon a proven solution that was once affordable only to large OEMs and Tier 1 suppliers.

"*Romax Enduro* takes so many parameters into consideration. It's easy to use, fast and really safe and that's reassuring for our customers," said Martin Mijno, CEO at Reckon Drives. "With this software we can see where the weak points are in our design and make them stronger by revealing the truth of what's happening within the gearbox. Using *Romax Enduro*, Reckon is able to make precise and professional client recommendations. From a customer point of view, sizing a gearbox using standard catalogs is increasingly seen as unprecise and risky, and a growing number of engineers are beginning to challenge datasheet values. Many suppliers from Europe or Asia understood that customer engineers prefer selecting gearboxes having a high torque rating, so they have modified their catalogs with higher ratings for the same products. We want to go the other way around and offer superior safety by proving that our torque ratings are the safest."

Lifetime and Performance Simulation

Ensuring durability performance without exclusively relying on expensive physical testing means simulation is key. Being able to create a detailed structural analysis of virtually any drivetrain, analyze its durability performance, and make changes where required, allows users to realize an optimal design whilst reducing the need for prototyping.

One option is to use a combination of finite element tools to predict loads and misalignments (which can be an extremely time-consuming process) and component specific tools for analysis and ratings. However, these simulations are not coupled together, which means important component interactions aren't captured.

Productivity and quality can also be negatively affected as two copies of the model have to be built and subsequent changes replicated manually. Furthermore, whilst component specific tools may offer a wide range of rating standards, they do not provide the required level of sophistication and structural analysis.

Romax Enduro is one of six products recently launched on the *Romax Nexus* platform. The platform comprises a suite of products which align with the drivetrain and transmission development cycle, from rapid modelling and concept exploration to detailed simulation and virtual product sign-off. The flexible products use workflow-oriented environments and seamlessly blend desktop and cloud technologies. All products work seamlessly together, which offers a level of process integration that enables true multi-attribute optimization via repeatable, automatable processes. Customers are using *Romax Nexus* products to achieve their development goals in the design of next generation propulsion systems, and exceed their targets for durability, efficiency, and NVH in cost-effective fashion.

Romax Enduro's customers particularly value its speed and trustworthiness, and rely on its wide-ranging features, including internal FE meshing, highly intelligent CAD integration, and powerful ability to handle large duty cycles. Reckon Drives has been impressed with the capability it brings in optimizing their design and development.

"Romax goes further and works with the most respected experts around the world to develop their own additional algorithms for bearing calculations. Because even the greatest products cannot perform if poorly sized, Reckon engineers use *Romax Enduro* to give our customers the perfect recommendation, so their application achieves the longest lifetime and the best performance," Martin Mijno said. **PTE**

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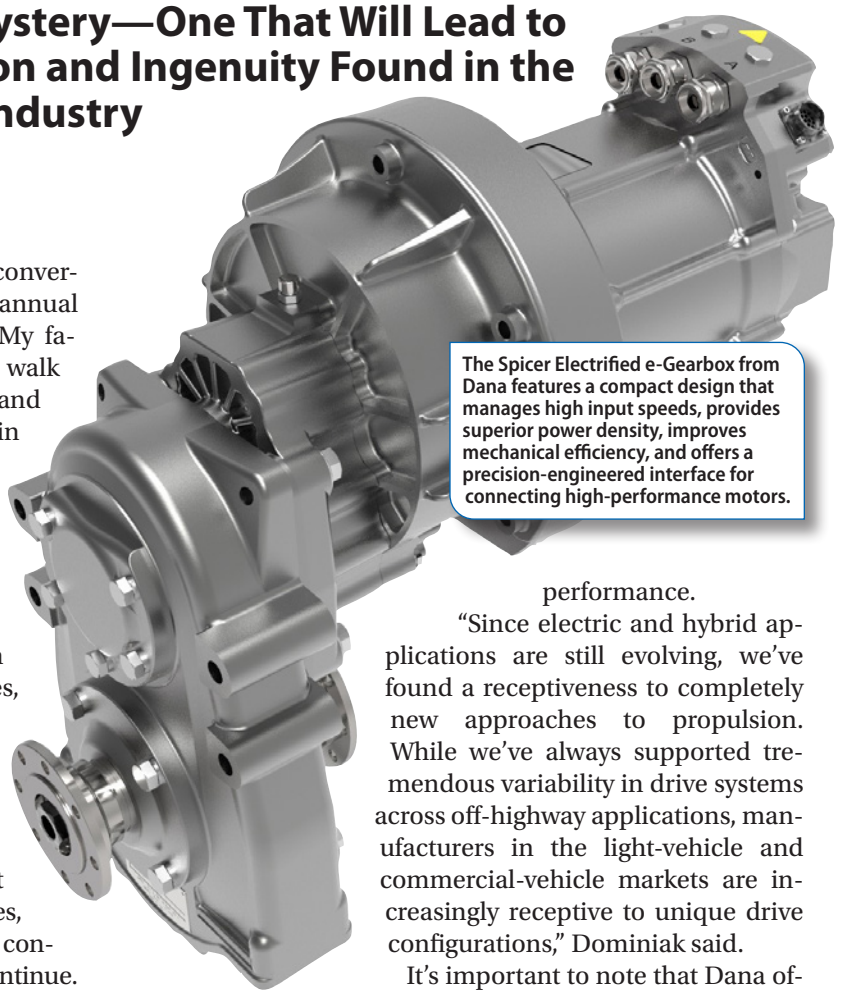
The Dynamic Drive Toward Vehicle Electrification

The Future of E-Mobility is a Mystery—One That Will Lead to the Same Innovation, Disruption and Ingenuity Found in the Early Days of the Automotive Industry

Matthew Jaster, Senior Editor



The Spicer Electrified e-Gearbox from Dana features a compact design that manages high input speeds, provides superior power density, improves mechanical efficiency, and offers a precision-engineered interface for connecting high-performance motors.

I will miss the presentations, the debates, and the conversations that were supposed to take place during the annual CTI Transmission Symposium in Novi, Michigan. My favorite ritual as a journalist covering the show was to walk around the tables and watch engineers, managers and manufacturers jot down their ideas on the notepads in front of them during the event. How many of these scribbled doodles and handwritten notes returned to the office and became the starting point for a concrete, sustainable transportation technology?

It's an exciting time to pioneer new technologies and drive systems for the future of the automotive, commercial vehicle, off-highway and transportation industries. There are so many different approaches, guidelines and needs in these markets across the globe that it feels like trying to put together a giant, 5,000-piece puzzle that should probably be divided into 25 smaller—more manageable—box sets.

Though the industry has been unable to come together face-to-face in recent months, it's safe to say that in lieu of trade show discussions debates on batteries, transmission technologies, charging stations, controls, connectivity, digitalization, and drive configurations continue. Companies like Dana, Schaeffler and Eaton recently shared some of their thoughts and ideas on E-mobility in 2020.

Dana Accelerates Electrification Strategy

Dana supplies power-conveyance and energy-management solutions for light vehicles, commercial vehicles, and off-highway equipment, and the company is advancing E-Mobility solutions across all these markets.

"The number one benefit our OEM customers and vehicle buyers are looking for in electric vehicles is performance," said Christophe Dominiak, senior vice president and chief technology officer at Dana Incorporated. "They want EVs that offer not only the same performance characteristics as gas- or diesel-powered vehicles, including speed, maneuverability, comfort, torque response, light weight, and range/operating hours, but they also seek low NVH and minimal weight."

While the company has varying degrees of influence over many of these characteristics, Dana improves performance primarily by optimizing the efficiency and power density of their products. They also develop electronic controls and data analysis solutions, which are critical for optimizing performance.

"Since electric and hybrid applications are still evolving, we've found a receptiveness to completely new approaches to propulsion. While we've always supported tremendous variability in drive systems across off-highway applications, manufacturers in the light-vehicle and commercial-vehicle markets are increasingly receptive to unique drive configurations," Dominiak said.

It's important to note that Dana offers a wide portfolio of thermal-management products that improve the durability, reliability, and efficiency of EVs by better managing the operating temperatures of batteries, power electronics, and other key components used in electric and hybrid vehicles.

"We've offered these types of thermal-management products for more than 20 years and won numerous awards for our technologies, which gives us a unique insight into the broader engineering challenges facing electric and hybrid vehicle manufacturers," Dominiak said.

Since Dana is heavily involved in the light-vehicle, commercial-vehicle, and off-highway markets, they see that the EV market is evolving at different rates across these markets and even within markets, especially off-highway.

For example, Dominiak said that the EV market in the light- and commercial-vehicle markets is progressing quickly, driven by increasingly stringent vehicle emissions regulations, the introduction of zero-emissions zones, government incentives, total cost of ownership, and buyer demand.

In off-highway, underground mining equipment, aerial work platforms, and construction equipment used in city centers are moving rapidly toward electrified drivetrains.

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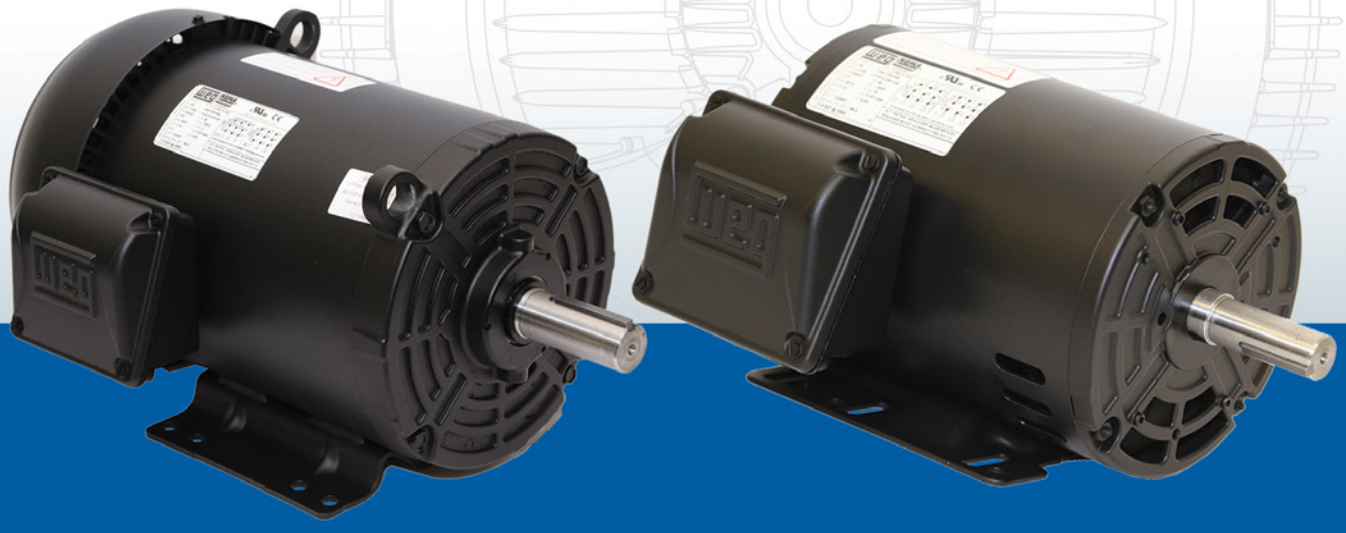

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The EV market is evolving at different rates across regions as well. The Chinese government has heavily incentivized the purchase of electric-drive automobiles, making it the world leader, while adoption in Western Europe was surging before the current economic downturn.

EV manufacturers and suppliers will face numerous challenges as the market moves toward higher output. The greatest challenges are continuing to extend vehicle range/working hours, bringing the costs of ownership in line with expectations, and establishing a charging infrastructure for plug-in electric vehicles.

"The movement toward electrified vehicles is truly an evolution, so our engineers involved in developing drivelines for traditional gas- and diesel-fueled vehicles are taking advantage of the opportunity to expand their skillsets to manage new engineering competencies, such as EV gear geometries and driveline tuning," Dominiak said. "We're also actively expanding our skillset throughout the company by training and hiring engineers with specializations in numerous areas, including mechatronics, electrical, software, and controls.

Dana electric motor production.

For example, the Dana Mechatronics Technical Center in Rovereto, Italy, identifies and leverages mechatronics system development opportunities with OEMs, facilitates co-development and networking opportunities with high-tech collaborators, and attracts engineering talent.

The engineers in Rovereto perform systems and components design and validation; technology evaluations and comparisons; proof-of-performance vehicle prototype development; feasibility and performance evaluations; and other advanced engineering functions. They're also deployed to support Dana engineering teams developing specific products for customers around the globe.

"We've also added valuable expertise through our acquisitions of TM4, Nordresa, and the SME Group, which have added critical motor and inverter competencies, as well as integration and application engineering expertise. Obviously, the integration of these capabilities is key in delivering effective solutions to market in a timely way," Dominiak said.

To demonstrate how Dana is continuously elevating their capabilities to the highest industry standards, the technical centers are going through rigorous engineering appraisal processes, including CMMI certification for product development as well as the Automotive SPICE certification for software development.

Given the current economic conditions, it's impossible to predict how quickly the EV market will progress in the very near term, but Dominiak firmly believes that the market share of EVs will continue to grow in the long term across all the vehicle markets.

"Over the past year, we have accelerated our capabilities in vehicle electrification, delivering all the elements of a complete, fully integrated electrified system across all mobility markets in any region of the world," Dominiak said. "In addition to our targeted investment in mechatronics research and development, we've made 7 acquisitions since 2017 to position us for success amidst the shift toward electrification."

Schaeffler Touts Innovation in E-Mobility

Schaeffler is a global company with over 11,000 customers worldwide. Now, more than ever, it is apparent that different customers in different countries want different things from an E-mobility perspective, according to Chris Shamie, vice president, hybrid, eAxles and PMO at Schaeffler Group USA.

"For that reason, Schaeffler is 'backing all horses' by offering engineered components, engineered systems and anything in between," Shamie said.

A common denominator of Schaeffler's E-Mobility technology is power density. They are continuously working hard to deliver innovative engineered solutions that do more in a smaller footprint.

"In the US, our customers really look at the overall value equation. Batteries cost somewhere between $150 and $200 per kWh capacity. Most modern BEVs will have at least 75 kWh battery which will cost perhaps $15,000, so each percentage point of overall vehicle efficiency is worth $150. With that in mind, our customers are looking for ways to reduce mechanical and electrical losses to reduce battery costs. As battery costs continue to come down, that loss reduction could be used to increase vehicle range," Shamie said.

Modularity is also important in the hybrid space. If an OE customer can use the same vehicle structure for both a conventional powertrain and a hybrid powertrain, the savings are immense.

The greatest challenge in meeting the needs of the EV market is that everyone wants something different.

"If you consider the traditional powertrain market in the

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old days, an OE customer would have a limited number of engines that would be mated to a limited number of transmissions. Components and systems would often be used across multiple powerpack combinations to boost economies of scale. Often suppliers could market a component or system to multiple OE customers because the powertrain paradigm was very similar across the globe," Shamie said.

Mobility-as-a-service customers might like million-mile durability and low total cost of ownership, but power isn't so important. Pickup truck customers want to be able to tow the world, while energy costs are less important. In Europe, CO_2 reduction is king. These different attributes lead to different ideal propulsion systems, and this hurts the ability for the industry to take advantage of economies of scale.

"While Schaeffler is known for its mechanical products, we've been producing automotive mechatronic products for over 25 years. This background has given us a huge head start for a wider implementation of a mechatronics curriculum," Shamie said.

To prepare the company for a broader life in mechatronics, Schaeffler takes a multifaceted approach.

"First off, we invest in our current team. Schaeffler is fortunate to have an army of good engineers that are passionate about cars. If you have a good engineering skill set and a passion to grow that skill set, with a training investment we can easily pivot to learn new engineering disciplines," Shamie said.

Next, the company works closely with universities to bring in the best talent early on through co-ops and internships. While this is nothing new for Schaeffler, they have put more emphasis on finding electrical engineers and software engineers from these programs.

Finally, as powertrains rely less on drivers and more on software (as delivered in supplied mechatronic systems) the need for functional safety and software quality systems cannot be overstated.

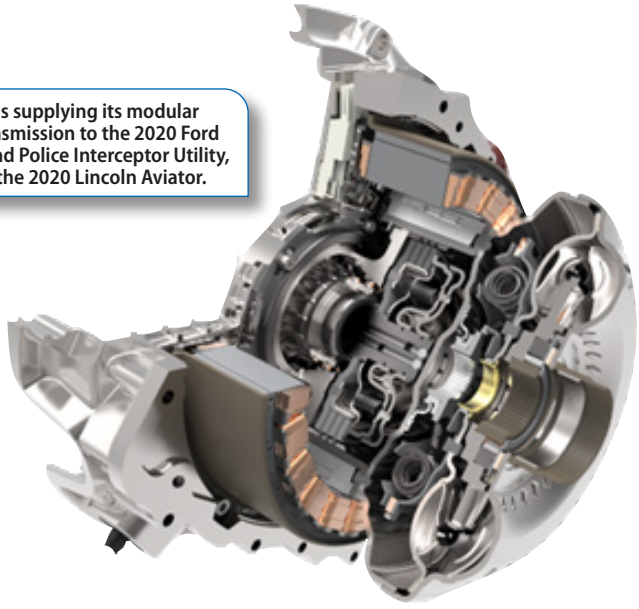
"When Schaeffler was supplying purely mechanical products, the OE customer would give a requirements list with maybe 100 characteristics that must be met. With mechatronic systems, that list of requirements will have tens of thousands of characteristics that we must deliver. While the fundamentals of our engineering activities did not change, we needed to automate our product development processes to track these thousands of requirements and ensure that we deliver a safe and robust product to our customers," Shamie added.

Shamie said looking back at the early days of the automotive industry, the first few decades were wild.

"We had hundreds of car companies competing for market. We had many different powertrain concepts with different body shapes, different passenger configurations, different levels of safety, and different price points. (Some of the first cars were BEVs!) The free market reigned, and those hundreds of companies dwindled down to around 20. And all those different powertrain architectures funneled down to one main one: an internal combustion engine spinning a multi-speed transmission," he said.

Shamie believes we are going back to those early days where we will see many new companies using different powertrains: ICEs with improved efficiency, parallel hybrids with improved performance and reduced emissions, dedicated hybrids with even better emissions, pure battery electric vehicles with eAxles, and people movers with in-wheel drives.

"Schaeffler is already in all these markets, and we will continue our long history of innovation to make each of these technologies better to improve the value equation," Shamie said. "Eventually the people will pick a new powertrain paradigm, and we will be there to give the market what it wants."



Schaeffler is supplying its modular hybrid transmission to the 2020 Ford Explorer and Police Interceptor Utility, as well as the 2020 Lincoln Aviator.

Eaton Looks to Expansion in EV Market

Eaton's eMobility business continues to regularly launch new technologies for the growing electric vehicle industry. They currently focus on three areas of the EV system: power electronics; power distribution and protection; and power systems.

Breaktor, for example, is designed to handle higher voltages than that of competing circuit protection devices. Electrified vehicle manufacturers have increasingly begun to raise the voltage levels on their products to boost range and performance. Breaktor is ideally suited to enable this voltage growth trend.

Eaton has produced industrial circuit breakers and relays for more than 70 years, so even the highest vehicle system voltage is still considered low- or medium-voltage in industrial applications.

"Conventional protection has contradicting design requirements that creates coordination challenges, which can lead to nuisance tripping and significantly reduced reaction time in short circuits or overloads, especially in higher powered battery-electric applications. With less than 5-millisecond actuation up to 1,000 volts and 30,000 amps, Breaktor improves vehicle safety and protects components from any level of overcurrent condition more effectively than traditional circuit protection methods," said Brian McKay, Ph.D., global head of engineering, E-Mobility at Eaton.

Eaton has seen increased demand for intelligent power

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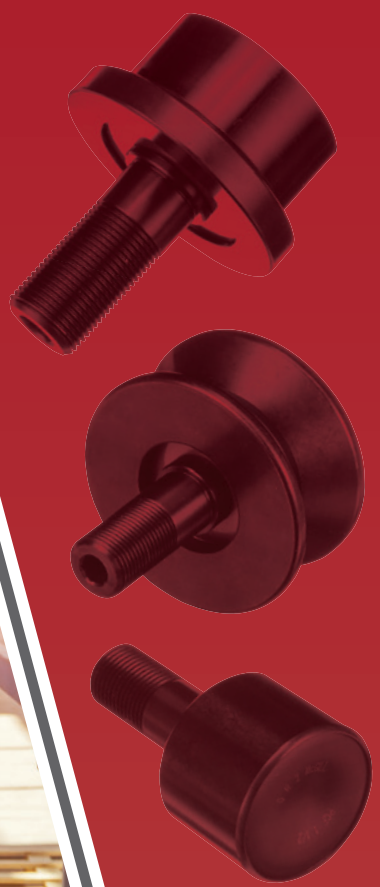

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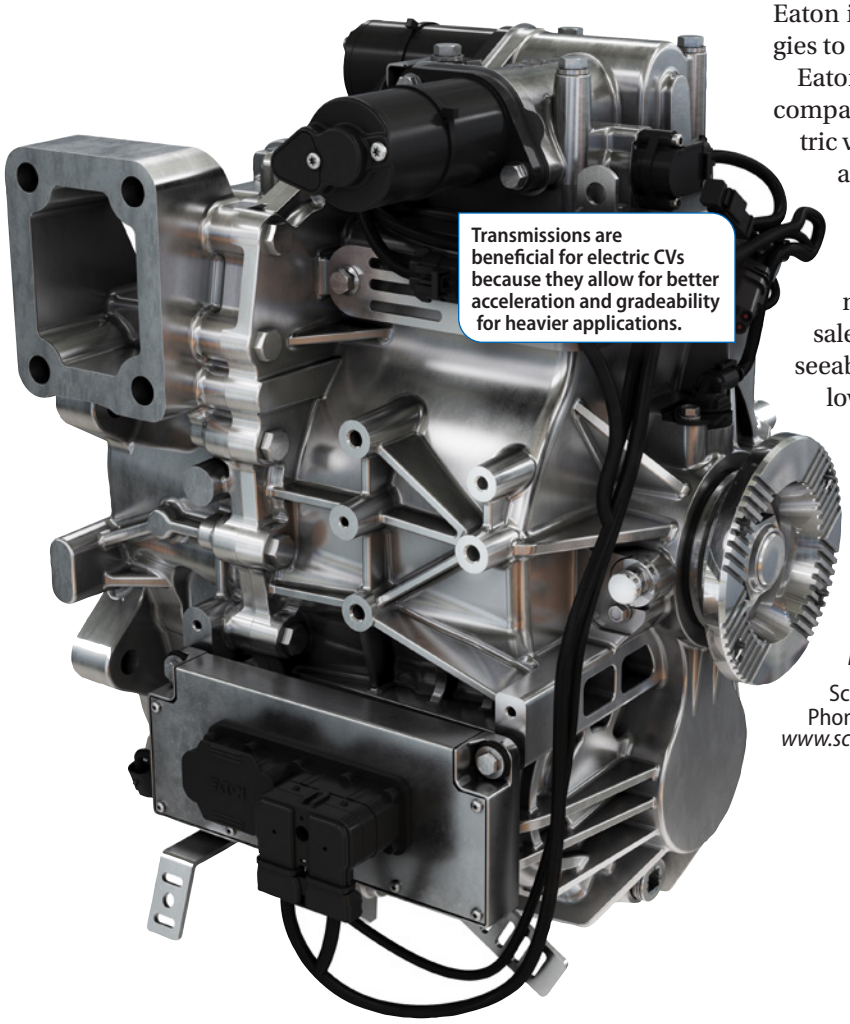
electronics, power systems, and advanced power distribution and circuit protection, according to McKay. The power distribution and protection category which includes fuses, supercapacitors and power distribution units (PDUs), while converters and on-board chargers fall under the power electronics umbrella. Power systems include electric vehicle transmissions for a variety of medium- and heavy-duty applications, as well as a 48-volt regenerative accessory drive system for heavy-duty trucks.

"Eaton has been in the electric business for years. We formed E-Mobility to combine elements of our Electrical Sector with our Vehicle Group. Eaton has extensive knowledge of vehicle dynamics, management of electrical power and vehicle safety standards," McKay said.

Eaton sells a great number of electrified parts/components, including high-voltage fuses, on-board chargers, inverters, DC/DC converters, and electrified vehicle transmissions. Eaton is a market leader in high-voltage fuses for electrified vehicles.

The electric vehicle passenger car market has grown steadily in recent years, in terms of both the number of vehicles available in the market and in sales. Regulations also are driving electrification. There is a demand for improved fuel economy and efficiency in the passenger and commercial vehicle markets, and it's always a value proposition. Is the cost to add that technology worth the investment?



Transmissions are beneficial for electric CVs because they allow for better acceleration and gradeability for heavier applications.

McKay said that Eaton has solutions that are very cost effective, and they also know that in certain markets, such as China, it doesn't matter what the U.S. is doing with regulations, they're going to battery electric vehicles. And it's the same in Europe.

"Automakers have aggressive growth strategies for EVs for two reasons: consumer demand and to meet increasingly stringent governmental regulations to reduce emissions and improve fuel economy," McKay said.

The expected growth in the EV market for passenger vehicles, as well as for buses and medium- and heavy-duty trucks, will create increased demand for the components needed to electric vehicles: batteries, EV transmissions, circuit protection, on-board chargers, power distribution units, and more.

Eaton's E-Mobility division provides an array of power conversion, management and distribution solutions, making it well-positioned to support automakers and truck and bus manufacturers to meet demand for EVs.

"Our advancements in the components in power electronics, power systems, and power distribution can help our OEMs with a variety of challenges like increasing range, enhancing safety and improving serviceability," McKay added.

While alternative powertrains are expected to increase market share, Eaton does not see the internal combustion engine going away. Because demand for gasoline and diesel engines will remain for passenger and commercial vehicles, Eaton is also focused on developing and refining technologies to reduce CO_2 and NOX.

Eaton's eMobility business combines elements of the company's electrical and vehicle businesses to deliver electric vehicle solutions to passenger car, commercial vehicle and off-highway OEMs.

"While we reply on automotive sales and production forecasting experts for specifics on the future of the EV market, there is no doubt the number of EV models entering the market, as well as production and sales, will continue to increase dramatically for the foreseeable future. The largest expected growth is in China, followed by Europe. EV growth in the U.S. is smaller, but slow and steady increases are expected," McKay said.

PTE

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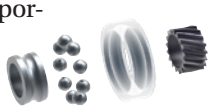
Limitations of the Timoshenko Beam Theory

FVA Offers FE Shaft Calculations in the FVA-Workbench

The *FVA-Workbench* is a manufacturer-neutral tool for the simulation and calculation of transmission systems. As product development cycles become shorter, powerful modeling approaches and calculation algorithms become increasingly important. The predominantly analytical approaches in the *FVA-Workbench* deliver fast and reliable solutions to all important issues related to drive technology and intuitive modeling techniques guarantee consistent, valid, and manufacturable gears every time.



The calculations are developed, analyzed, and validated in research projects by Forschungsvereinigung Antriebstechnik e.V. (FVA, the German research association for drive technology). Through membership fees and public funding, the FVA organizes 17 million euros annually in research projects at leading German universities, chairs, and research institutions.

FE Calculations in the FVA-Workbench

The calculation approaches in the *FVA-Workbench* are based on analytical methods that have been known for decades in the drive technology industry and validated by innumerable FVA e.V. research projects. These solutions deliver high-performance calculations while at the same time also producing high-quality results. However, not all bodies can be analytically described with accuracy. For this reason, casings, planet carriers, wheel bodies, and shafts in are considered using finite element analysis in the *FVA-Workbench*. The FE approach is applicable for complex component geometries which can no longer be represented within the validity range of the analytical approaches (Figure 1). In the following, this difference will be explained using the example of the FEA shaft calculation approach recently integrated in version 5.6 of the *FVA-Workbench*.

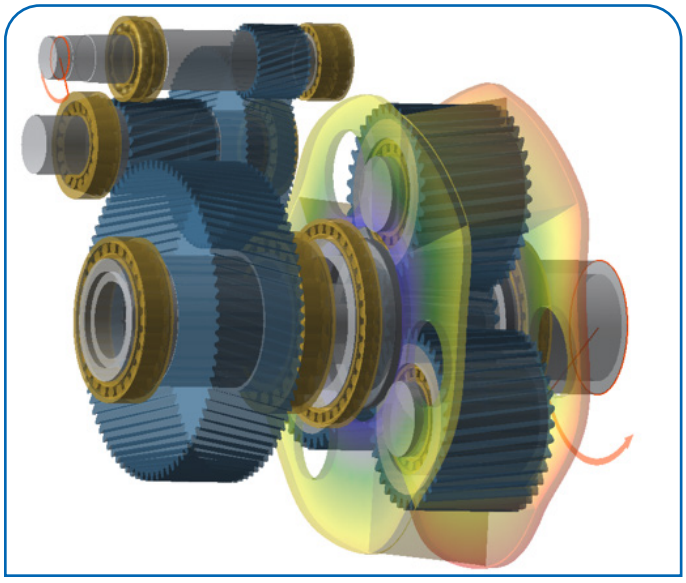


Figure 1 Deformed planet carrier in the FVA-Workbench.

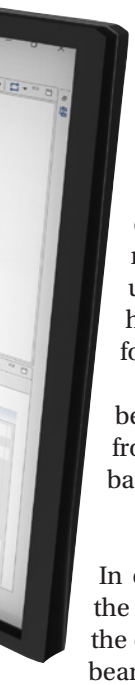
Calculation of Shaft Deformation

In the *FVA-Workbench*, shaft deformation is calculated using the Timoshenko beam theory. In this approach, the bending deformation according to the Euler/Bernoulli method is combined with consideration of the shear deformation. The following limitations remain when using the Timoshenko approach:

- The cross-sectional surface of the component is not curved.
- Only rotationally symmetric components are calculated (solid and hollow shafts).
- Conical or curved contours are replaced by stepped cylindrical sections.
- Forces and moments are applied to the central axis at a point.
- The flow of forces in stepped shafts is not correctly considered.

For most common gear shaft geometries these limitations do not lead to any practice-relevant deviations compared to the actual shaft deformation. However, if more complex geometries are used, or to check whether the limitations of the Timoshenko beam theory lead to significant deviations for a shaft geometry, shaft deformations can also be calculated using FEM as of version 5.6 of the *FVA-Workbench*. Shafts generated within the *FVA-Workbench* can be internally

meshed for this purpose. For more complex geometries, shafts exported from CAD programs can be read and meshed. The meshing and determination of contact nodes with the rest of the gearbox model is largely automated. The user navigation has been designed for maximum efficiency, so that FE shafts can be modeled, meshed, and calculated as quickly as possible. Users can create a full-featured mesh for FE calculation in just a few clicks, without any special FE knowledge. This automatic meshing is possible because the deformation analysis performed places significantly lower demands on the mesh size than a stress analysis.



Calculation Example: Comparison of the Timoshenko and FE Methods

In the following, a stepped shaft will be used as an example to explain the difference between the FE calculation and calculation using the Timoshenko beam method. The comparative calculation was performed using a simplified shaft geometry (Figure 2). The shaft has dual support bearings and is loaded with a single force at the center.

The outer diameter of the central shaft section will be varied for the comparison. The conditions will range from 1 (smooth shaft) to 3.5 (very strong shoulder). The base diameter of the shaft is 50 mm.

FE Methods in the FVA-Workbench

In order to couple the stiffness of the FE elements with the analytical approaches, the stiffnesses are reduced to the coupling points. For shafts, the coupling points are the bearings, gears, load application points, or couplings. In the reduction, a stiffness matrix is determined for the coupling that describes the deformation behavior at the coupling points as well as the complete consideration of the entire FE component. Therefore, only the coupling points are visible in the calculation.

The deformations of the entire component can be calculated from the loads on the coupling points in a post-processing step. This procedure makes an extremely high-performance calculation possible taking the influence of all deformations in the gear into consideration. The influences on the gear are experimentally proved in FVA research project 592 II.

Figure 3 shows the maximum shaft deflection over the ratio of the outer diameter of the middle segment relative to the diameter of the adjacent shaft sections.

For smooth shafts the analytical method produces the same result as the FE calculation. However, from a diameter increase of 1.25, the analytical solution calculates a lower shaft deflection for this shaft geometry than the FE calculation. From a 3-fold increase in the diameter of the middle section, the FE calculation produces a constant 23% lower shaft deflection than the analytical approach.

In this case, the difference can be attributed to two causes. It is partially due to the uneven distribution of the flow of forces over the cross-section, and partially due to the curvature of the cross-section of the shaft in the area of the diameter step (Figure 4). As described above, neither of these effects are considered in the Timoshenko analytical approach.

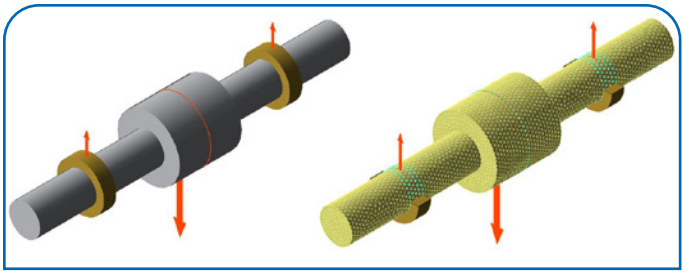


Figure 2 Example model of a gearbox shaft with dual bearing supports.

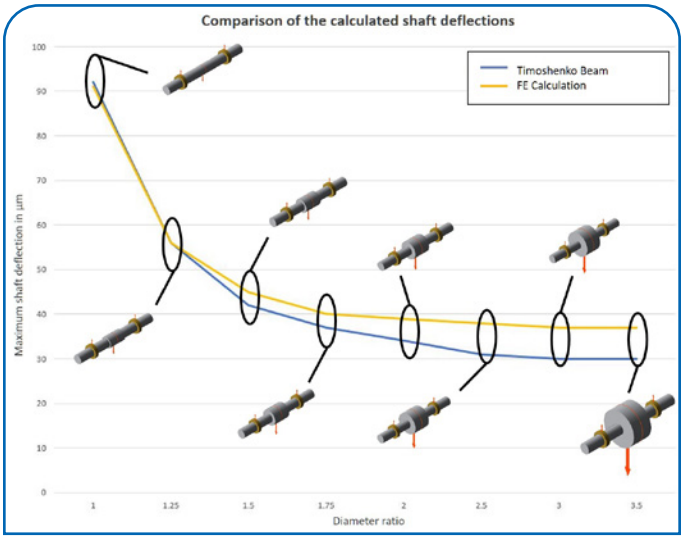


Figure 3 Comparison of Timoshenko and FE calculations.

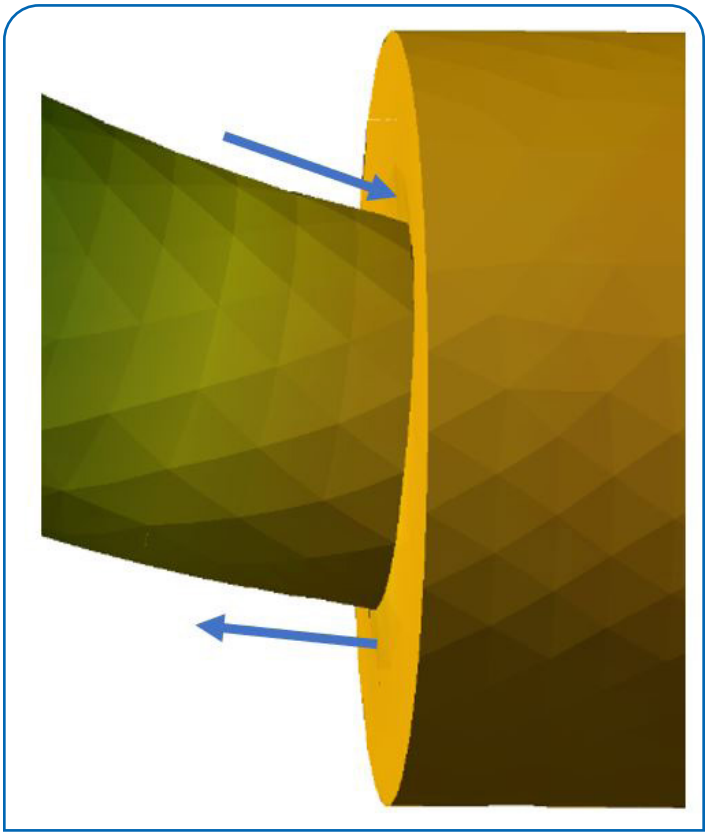


Figure 4 Curvature of the front surface.

Practical Example

The differences in the shaft deflection calculation methodology described above can also be seen in practical gearbox models, such as the bevel-cylindrical gear unit shown in Figure 5.

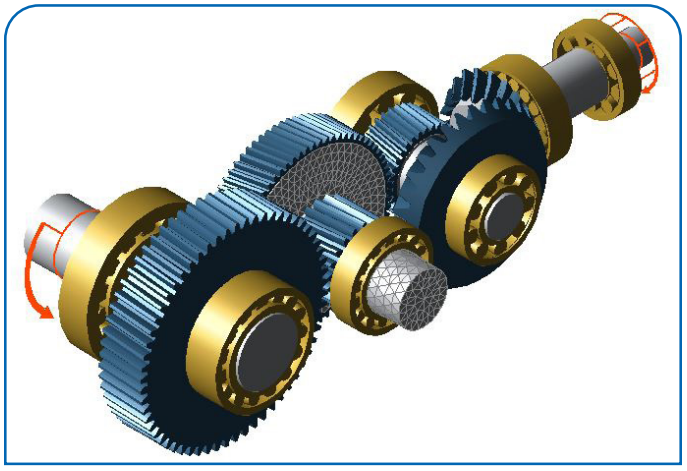


Figure 5 Bevel-cylindrical gear unit.

Here, the following variants of the load distribution across the face width of the output stage were performed for the intermediate shaft:

Analytical calculation of all shafts

FE calculation of the intermediate shaft, analytical calculation of all other shafts.

Figure 6 shows the load distribution across the face width for both calculated variants. Although the influence on the shaft deflection is not as strong here as in the theoretical example in Figure 2, a significant increase of the face load factor KHß from 1.22 to 1.27 can be observed for the FE calculation.

Realistic Representation of Shafts

As of version 5.6 of the *FVA-Workbench*, the detailed geometry of notches, such as feather keys, shaft shoulders with undercuts, and rectangular grooves, are accurately displayed in the 3d model to provide the user with graphical feedback on the specified geometry (Figure 7). These extensions will also be made regarding the implementation of FKM guidelines for calculation of shaft safeties in the next version of the *FVA-Workbench*, which will then supplement the current shaft safety calculations according to DIN 743. **PTE**

Figure 7 Realistic shaft representation in FVA-Workbench 5.6.

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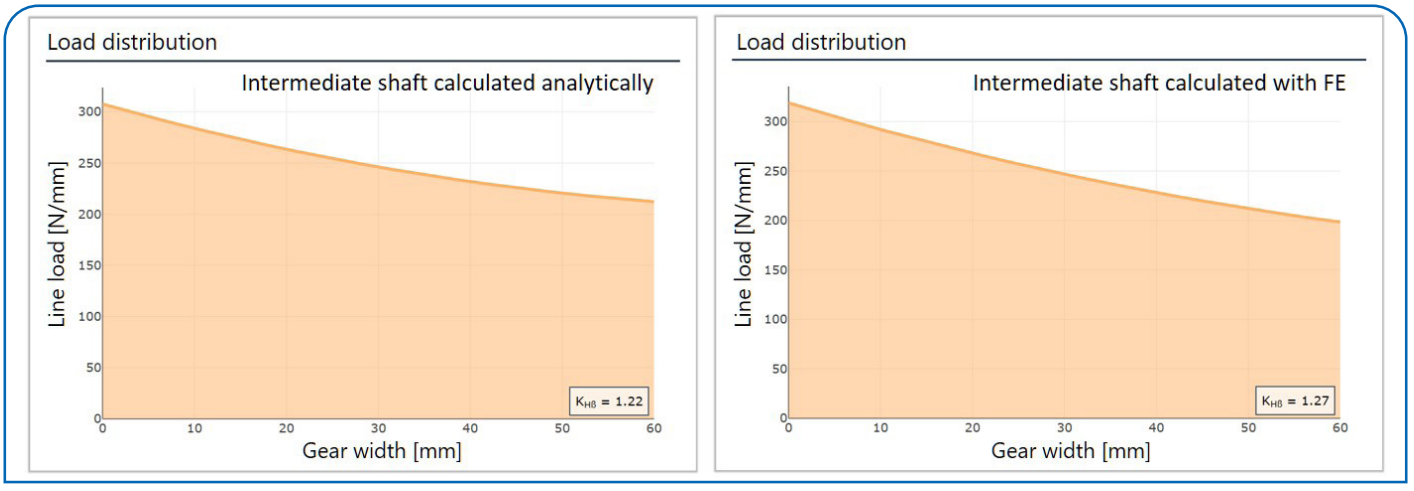

Figure 6 Comparison of the load distributions across the face width of the intermediate stage.


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Phase Management as a Strategy to Reduce Gear Whine in Idler Gear Sets

Robert White and Pravin Patil

Introduction

Gear whine is caused by transmission error, shuttling, friction, impacts, lubricant entrainment and air entrapment (Ref. 1). While the list of gear noise factors is fairly long, it should be recognized that the typical gear noise problem is not a result of lubricant entrainment or air entrapment. Impacts are due to corner contacts that might occur when the teeth just come into contact or due to interference at the root. Both are usually avoided by good gear design. Corner contact is avoided by applying appropriate relief to the teeth. Interference is avoided either by undercutting the flanks of the pinion teeth, by using long addendum pinion and short addendum gear teeth, or by increasing the pressure angle (Ref. 2). That leaves transmission error and other mesh forces.

The mesh forces are usually described as line of action (LOA) and off line of action (OLOA) forces, otherwise known as normal and tangential forces. The greatest line of action forces are from transmission error, which is a line of action displacement, and is the focus of this paper. Shuttling forces of helical gears also act along the line of action. The position of the force vector representing the mesh force shuttles axially as the gears rotate through one tooth mesh sequence. The bearings must react to the axial change in load position and therefore see a change of force that varies at tooth mesh frequency. Tooth friction forces are off line of action forces (Ref. 3). Shuttling and friction forces are generally regarded to be of lesser importance to gear noise but become important when the transmission error is very small.

Transmission error is the driven gear's deviation from perfect conjugate action and is the result of manufacturing geometry errors; gear tooth, shaft and housing deflections; mesh stiffness variation; and dynamics (Refs. 4–6). The dynamic forces generated within the gear mesh because of imperfect conjugate action are reacted at the bearings supporting the gears in the housing. These dynamic forces on the housing excite the housing causing it to vibrate. The housing surface vibration couples with the air causing pressure fluctuations that travel as sound pressure waves to our ears; we hear them as sound. Reducing transmission error is the preferred approach to reducing gear whine.

The forces acting in the gear mesh are made up of DC and AC forces. The DC mesh force is the necessary static force required for the gears to transmit power. This force is present by design. Static forces cause certain design challenges such as bearing life and shaft and housing deflection, but they don't cause gear noise. Gear noise is the result of the AC forces

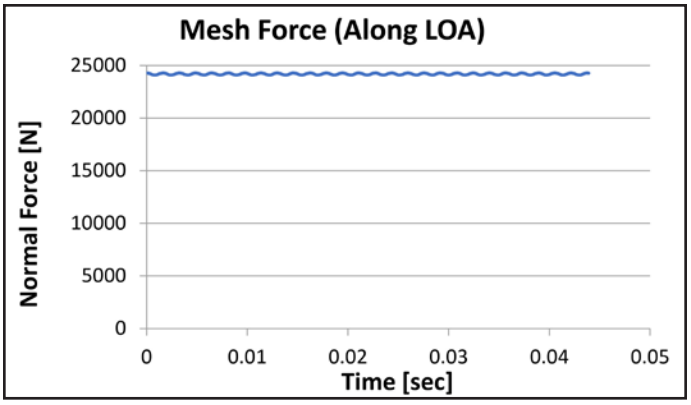

Figure 1 AC forces due to dynamics such as transmission error are very small in comparison to the DC mesh forces.

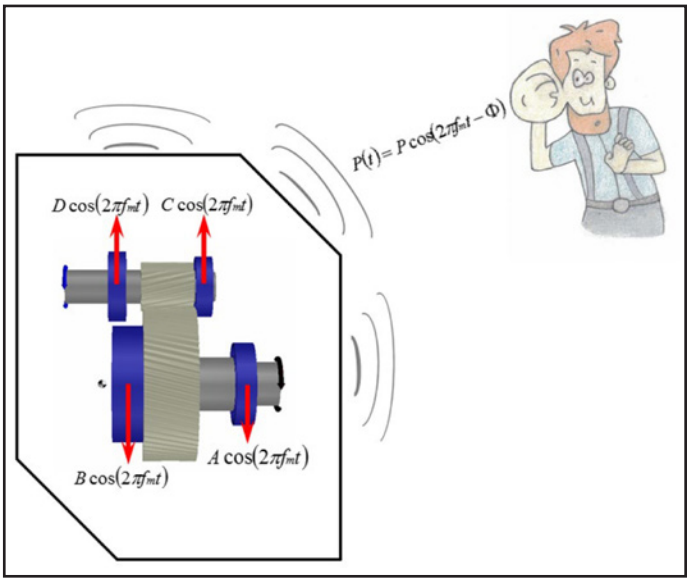

Figure 2 The red arrows indicate bearing forces, from the transmission error forces at the mesh, being applied to the gearbox. Notice all bearing forces for a single mesh are in phase.

from transmission error, shuttling, and friction, and are unintentional. These dynamic forces are tiny in comparison to the static forces. In the example to be discussed later, the DC mesh forces are in the magnitude of the weight of a pickup truck while the AC forces are less than a bag of dog food (Fig. 1). It is only these small AC forces that we are interested in from a noise perspective. Because all the bearing forces are resolved within the gearbox, summing all bearing reaction forces on the housing results in zero, yet there is noise. That is because the forces act on various locations of the gearbox.

Consider the two gear mesh of Figure 2. These transmission error forces at the bearings are in phase, that is, they reach maximum values simultaneously (assuming the gears' and shafts' first natural frequency is sufficiently greater than the mesh frequency).

Transmission error forces are managed by making gear microgeometry modifications. While transmission error can theoretically be reduced to zero at a single load, it is the gear designer's challenge to make transmission error small over a range of loads (Refs. 7-8). Transmissions that operate over a wide range of speed and load are especially challenging and the designer then must make choices about where in the operating space it is imperative to minimize transmission error.

Objectives

The objective of this paper is to show that in idler gear trains there is an additional opportunity for reducing gear whine. The idler forces acting on the idler bearings from the two idler meshes add vectorially to produce a transmission error force ellipse. This ellipse is swept through once per tooth mesh. It will be shown how one may manage the phase between the two meshes on the idlers to minimize the size of the ellipse. If the sum of the transmission error forces is reduced, the reaction forces at the bearings are reduced. Generally, reducing dynamic forces on the housing reduces noise.

The size and orientation of the transmission error force ellipse is managed by three "knobs," they are the number of teeth on the idler, idler tooth thickness and idler position (working pressure angles and which side of the line of centers connecting the input and output gears—things that affect the orientations of the lines of action). Rest assured, one still must well manage transmission error because even if the forces at the idler could be reduced to zero, there remain transmission error forces acting on the input and output gear bearings.

Designers are provided insights for reducing gear noise in idler gear systems. These concepts are demonstrated by means of a case history of a PTO gearbox whereby making phasing changes led to reduced gear whine.

Phase Study in Previous Work

The importance of phasing gears has been long appreciated in planetary circles. Schlegel and Mard claim noise reductions as much as 11 dB by using "system phasing," a strategy that sequences the meshes between pinions to "eliminate any external force or moment reaction" (Ref. 9). Independently, Seager developed a concept for "neutralizing" harmonic components of tooth excitations by carefully choosing the number of teeth on the sun and ring gears (Ref. 10). Neutralizing applies only to planetary gearing with equally spaced planets and complete neutralization can be obtained for torsional modes or transverse modes, but not both. Palmer and Fuehrer provide a table which indicates the neutralized torsional and transverse modes for various numbers of teeth on the sun gear (Ref. 11). They then introduce "counter-phasing" as the next step in the progression of planetary gear phasing. With counter-phasing, the planetary torsional stiffness variation is reduced, assuming that torsional modes are more important than transverse modes. Torsional modes are optimally neutralized "when the pinion phase angles φ_i are equal to different multiples of $360°/n$, where n is the number of pinions."

Kahraman and Blankenship extend the planet phasing ideas from a kinematic study into the dynamic realm (Ref. 12). Transmission error functions at the sun-planet and plant-ring meshes provide the dynamic excitation. The authors concluded that no one phasing option was indisputably better than another and that the best phasing choice may be application dependent. Similarly, Parker examined planet phasing for unequal planet spacing (Ref. 13). He shows how one can predict when rotational and translational or both forces cancel, thereby not causing excitation even while traversing a resonance.

Regarding parallel shaft gearing, Muehl and Sternfeld built a test rig with two gear meshes; this gearbox had two gears with the same number of teeth on the input shaft (Ref. 14). Load was applied to the two output shafts. A coupling between the two input gears allowed them to adjust the relative phase between the meshes. While they concluded that changing phase affected the measured sound power, they could not make a recommendation for what relative phase would result in the least noise as their results were confounded with other parameter changes such as different teeth in mesh.

Kubur, et al. focused on dynamic analyses of countershaft gearboxes (Ref. 15). One of the items they investigated was how bearing forces change with changes in the shaft layout as viewed along the shafts' axes. In their analyses the idler was a compound gear with different tooth counts for meshes with the input and output gears.

Cheon suggests one can reduce mesh stiffness variation in parallel axis spur gearing by adding a second set of identical gears phase shifted by half a tooth (Ref. 16). This is somewhat akin to double helical gears which is tantamount to two gears side by side but with opposite hand.

Brecher, et al. studied a two-stage gearbox (Ref. 17). Some of their runs were with both gears on the intermediate shaft with the same number of teeth. These were run in phase and shifted half a tooth. By shifting one-half tooth, their difference velocity level measurements reduced 3.5 dB for the fundamental mesh frequency and reduced 2.5 dB at the third harmonic (Difference velocity level is the measured transmission error in terms of angular velocity converted to dB with reference velocity 1e-6 m/s. The authors measured angular acceleration with two tangentially mounted accelerometers and integrated the signal to angular velocity.) There was no change at the second harmonic.

Kartik and Houser exercised a model to perform parametric analyses on an idler gearbox (Ref. 18). The computed dynamic force responses at each of the six bearings were used to predict the housing surface accelerations that were then used to calculate sound power. They investigated the effects of bearing stiffness, mesh stiffness, housing wall stiffness and mass, etc. They then ran simulations manipulating the phase of the two idler meshes. The baseline condition was the original gearbox arrangement, nearly in phase. They also considered the two meshes perfectly in phase and 180° out of phase. They found that the idler shaft bearings responded to the phase change, as expected, but the input shaft bearings

responded as well. They reported "a significant drop in the sound level at the lower frequencies when the meshes are in opposite phase, with a maximum reduction of about 45–50 dB at the peak of lowest natural frequency."

Liu and Parker compared various techniques for dynamic modeling of non-linear idler gear systems (Ref. 19). They compare lumped parameter models, the harmonic balance method and perturbation analysis. These were then compared against the numerical integration method.

The Transmission Error Force Ellipse

The importance of phase will be underscored by considering virtual gear noise analyses. In a gearbox with an idler like the schematic shown in Figure 3, there was an inordinate amount of gear noise. The input and output gears were supported by the stiff bearing supports on the ends of the gearbox, however the idler support was directly tied to the surface of the housing. While the idler bearing stiffness was sufficient to carry the static bearing loads, it is thought that applying transmission error forces directly to the housing skin is an efficient way to cause the housing surface to vibrate and therefore transmit noise. This idea was reinforced by other gear pairs in the same gearbox with similar calculated transmission error that went directly from the input to output shaft, not employing an idler, and not causing gear noise problems.

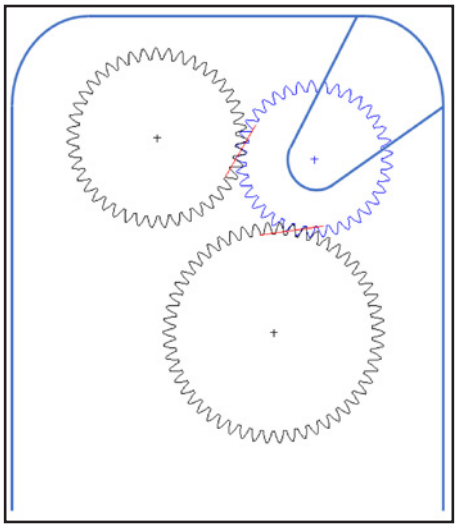

Figure 3 Gearbox with an idler set — input at the top (CCW rotation) and output at the bottom.

To further explore this theory, the transmission error reaction forces were applied to the housing at the bearings for the three gears, all together and individually. The response variable for this analysis was the gearbox average surface velocity since noise is generally assumed to be related to surface velocity. Figure 4 shows that the response due to the transmission error forces acting on the input (DriveR) and output (DriveN) shafts alone, shown in blue and green, had minimal contribution to the total response. The response from the idler transmission error forces, shown in red, however, was nearly equal to the total response, shown as light blue.

In this phase analysis, transmission error forces were assumed to be at the fundamental mesh frequency and have unit amplitude. Phase was calculated by the method outlined in Appendix A. The phase is a function of the number of teeth on the idler, idler tooth thickness and the directions of the lines of action. The transmission error forces from the two meshes of the idler are summed by vector addition at every instant in time. These are only the tiny AC forces that ride on top of the very large DC forces; that is why they appear as sinusoids. As the gears rotate through a single tooth mesh cycle, the summation of the force vectors at the idler sweeps out an ellipse (Fig. 5).

The size, shape and orientation of the ellipse can be managed, however, by carefully selecting idler parameters such as number of teeth, tooth thickness and its position. Since

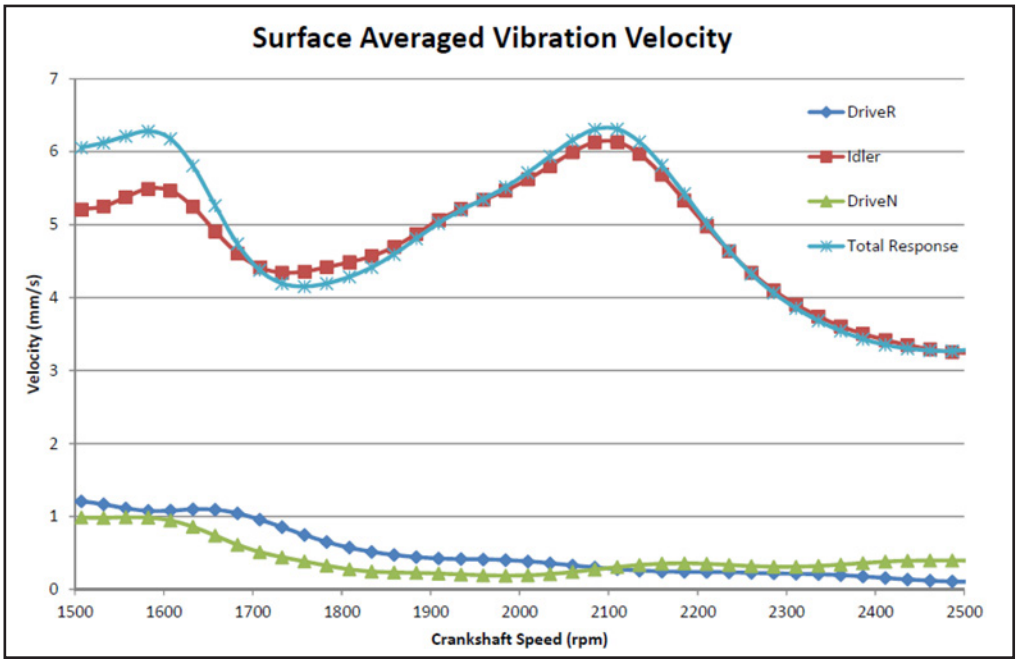

Figure 4 Average surface velocity on the transmission case with bearing forces applied to the housing of Figure 3 one shaft at a time, and all together, for a total response.

the force vectors are parallel to the lines of action, the principal axes of the ellipse bisect the two idler lines of action. This means that the orientation of the ellipse is defined by the location of the idler. It is not yet determined which is the major and which is the minor axis; that requires the number of teeth and tooth thickness.

To demonstrate the sensitivity of the ellipse to the number of teeth, the transmission error force ellipses are calculated for many different idlers with the same tooth thickness (Fig. 6). Because the number of teeth changed, the idler center had to change accordingly — these have constant pressure angles. Because the pressure angles were kept constant, the alignment of the ellipse axes is maintained.

We can see that in this over-plot of many ellipses, some are much smaller and others are rotated 90 deg. Let's look at a few of these ellipses more closely. Notice in Figure 3 that the idler is connected to the housing at the upper right. It is therefore logical that forces in that direction are very efficient at adding vibration energy to the housing skin. Likewise, ellipses with major axes oriented up and to the right would produce more surface vibration. The black ellipse of Figure 7 is the baseline idler ellipse of the gear train analyzed in Figures 3 to 5. The 18T ellipse (blue) might be a better choice because it is significantly smaller than the black ellipse. The 31T ellipse (red) is even shorter in the direction of the 37T major axis and perhaps would produce less noise. One would expect, however, that it would produce more side to side motion, but this might not produce as much radiated sound. Depending on how the idlers bearings are attached to the housing, the ellipse orientation may be important, so an acceptable choice need not be a small ellipse, just be in a favorable orientation.

The effect of changing tooth thickness without changing the number of teeth or the position of the idler has the effect

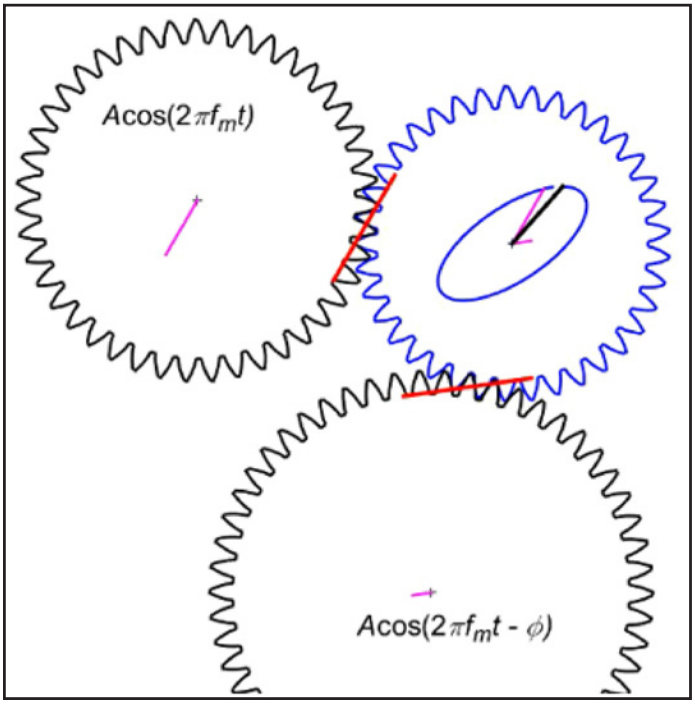

Figure 5 Unit amplitude transmission error force vectors (pink), parallel to the lines of action (red), are applied to the gears and reacted at the bearings. The forces are sinusoidal at mesh frequency and phase shifted. At the idler, the summation of the transmission error force vectors from the two meshes are added to make the resultant vector (black). The resultant vector sweeps through an ellipse as the gears rotate through a single gear tooth mesh cycle.

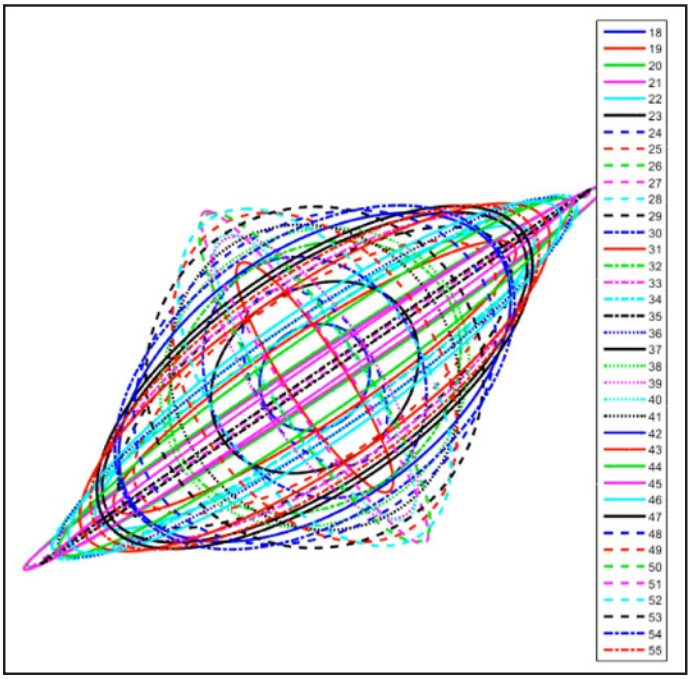

Figure 6 Collection of transmission error force ellipses generated by changing idler tooth count from 18 to 55 teeth while maintaining the same tooth thickness and the same pressure angles.

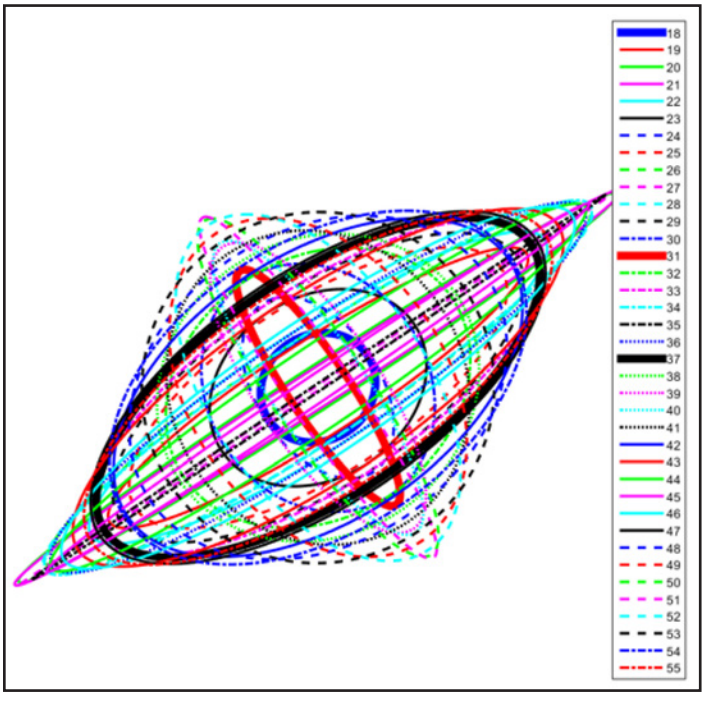

Figure 7 The transmission error force ellipses of Figure 6, highlighting specific ellipses.

shown in Figure 8. While the ellipse can be affected, it cannot be manipulated nearly as much as by changing the tooth count, mostly because tooth thickness can only be changed so much.

Transmission error forces act along the lines of action, which in turn, define the orientation of the ellipse. That

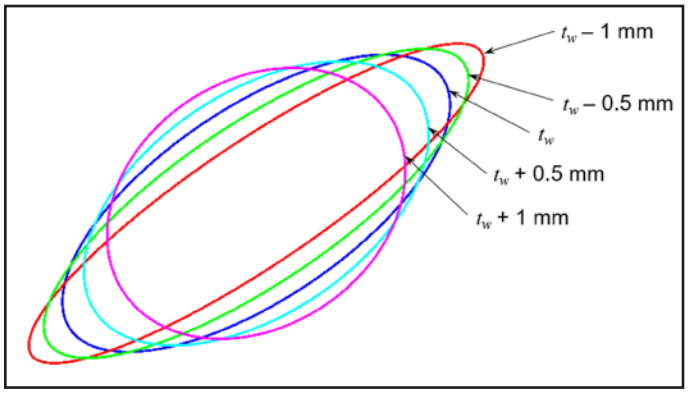

Figure 8 Transmission error force ellipses from the gearbox of Figure 5 showing how their sizes and shapes are affected by only changing idler tooth thickness; baseline tooth thickness is t_w.

means there is significance to which side of the line of centers connecting the input and output gears that the idler is on. On one side, the lines of action tend to be more parallel and on the other more perpendicular. One can't produce a small ellipse if the lines of action are perpendicular. On the other hand, when the lines of action are parallel, the DC bearing forces are greater and bearing life is reduced. Such are the compromises of the designer!

Manipulating the phase at the idler likewise affects the phase at the output gear relative to the input gear. While controlling the input and output phases on the input and output shaft bearings is a theoretical method for reducing the sound radiated off the housing, it is not very practical, because if it works, it is only over narrow speed ranges. Furthermore, identifying the desired relative phase that would minimize gear noise is not trivial.

Describing the Size of an Ellipse

Since we expect that the size of an ellipse is important in determining which idler design is better than another, it is important that we have a way to describe an ellipse's size. In some cases, only the dimension in a specific direction may be important, i.e. direction cosines, describing the angle off the horizontal to the major axis. In the general case we want to capture the overall size of the ellipse regardless of orientation. While area of the ellipse seems to be a natural choice, there are ellipses that are flat (the minor axis is zero) therefore the area is zero. This is much different than an ellipse that collapses to a point because the lines of action are parallel and the phase is exactly 180°.

The size descriptor proposed is the root of the sum of the squares of the major and minor axis lengths as shown in Figure 9 and Eq. 1. Because we are addressing noise, it is desirable to also have a dB descriptor; one is proposed in Eq. 2. Notice that its format is similar to definitions for vibration or sound level in dB, making it suitable for comparing one ellipse against a reference ellipse, perhaps the baseline design, when one exists. Alternatively, RSS_0 could be unity.

$$RSS = \sqrt{a^2+b^2} \tag{1}$$

$$\text{dB} = 20\log\left(\frac{RSS}{RSS_0}\right) \tag{2}$$

Underlying Assumptions

The two underlying assumptions for this phasing work are that the magnitudes of transmission error forces are approxi-

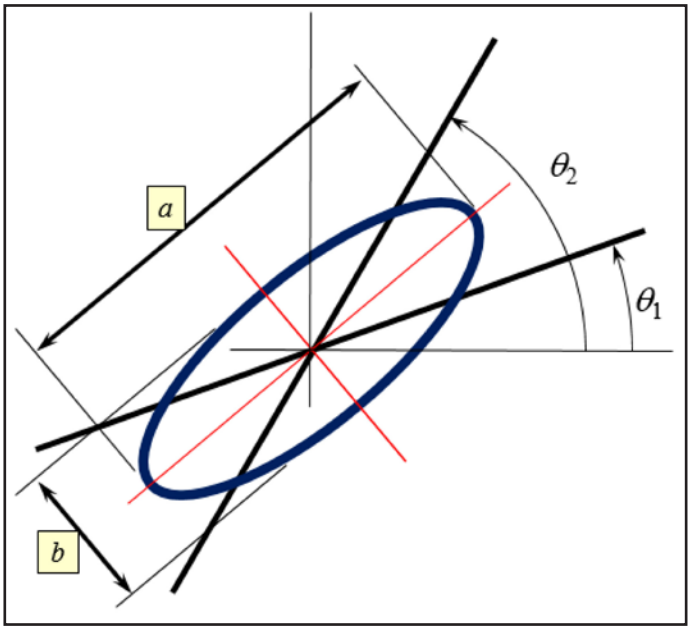

Figure 9 Descriptors for comparing size of ellipses; the *a*-dimension is halfway between the lines of action, oriented at an angle of $(\theta_1+\theta_2)/2$.

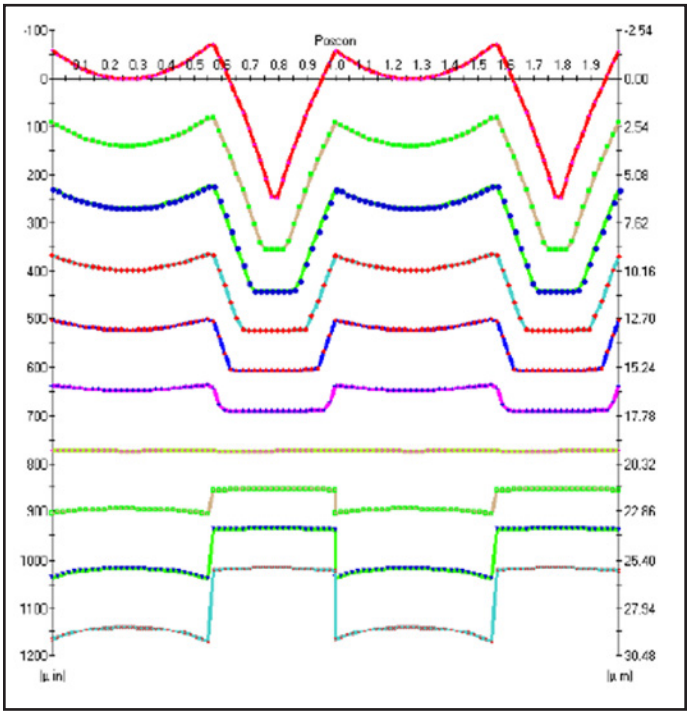

Figure 10 Harris map of low contact ratio spur gears at various loads with profile modification optimized for a specific load; the discontinuities are the highest and lowest points of single tooth contact (from Ref. 1).

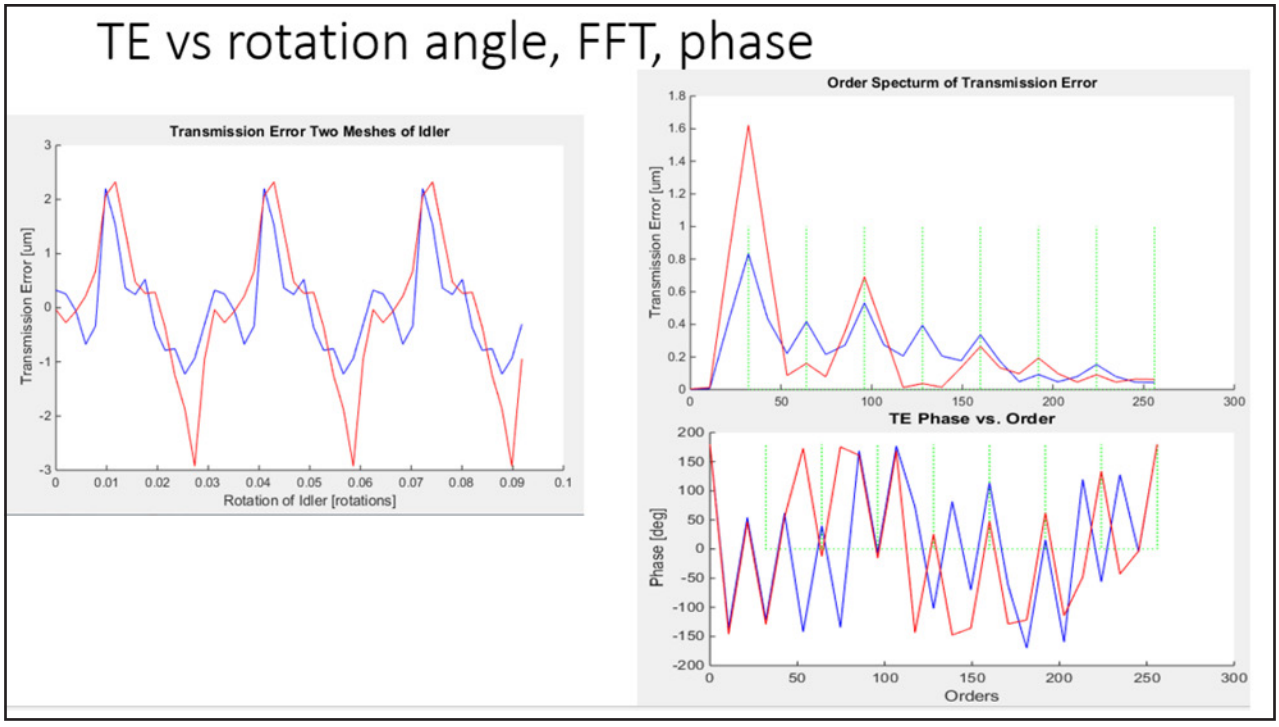

Figure 11 **Transmission error vs rotation for the two meshes of an idler and the corresponding FFT with amplitudes and phase. Vertical green lines in the frequency plots indicate harmonics of mesh frequency.**

mately equal at the two idler meshes and the transmission error; error forces are symmetric about the midpoint between the lowest and highest points of single tooth contact. These assumptions are now addressed.

The TE force ellipse up to this point was generated by using unit force vectors parallel to the lines of action acting on the idler, with the proper phase. What if the TE forces are not equal? How does one know the relative phase of the transmission error forces between the two meshes? Transmission error forces are not the only gear mesh forces acting on the idler bearings. Must we account for those other forces? Only the fundamental mesh frequency has been considered. What about harmonics?

One might expect the transmission error forces to be of roughly the same magnitude on each mesh of the idler since the manufacturing methods and design philosophies are likely the same. One can further expect that the forces will tend to be symmetric about the midpoint between the lowest and highest points of single tooth contact by inspecting Harris plots (Fig. 10). Figure 11 shows that the transmission error waveforms are somewhat similar for the two meshes and fairly aligned relative to the midpoint between the lowest and highest points of single tooth contact. This plot was created by using the transmission error vs. roll angle data from a virtual analysis, but then plotting it as TE vs. idler rotation.

The FFT (Fig. 11, upper right) shows that for one mesh (red) the amplitude of the transmission error at the fundamental frequency was significantly greater than the other mesh (blue). How does that stack up against the assumption that transmission error forces are the same magnitude? Figure 12 plots, in blue, the sizes of the ellipses of Figure 6, normalized by dividing each RSS magnitude by the maximum RSS magnitude. In this first analysis, both TE force vectors were unity.

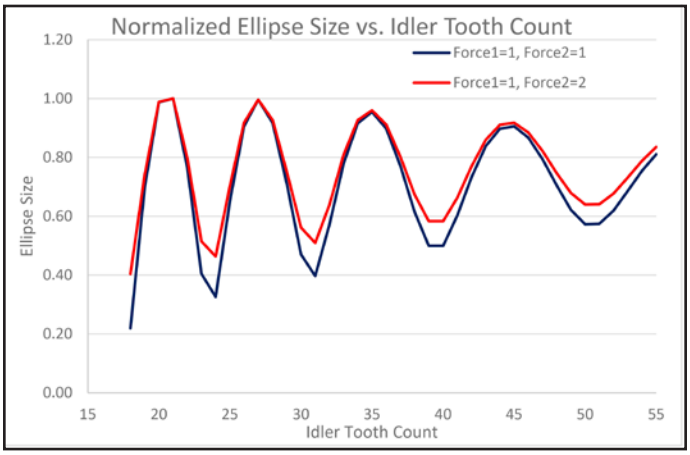

Figure 12 **Normalized RSS for ellipses of Figure 6 by first considering both TE forces as unit forces (blue) and then with the second force twice the magnitude of the first (red). Normalized RSS = RSS/max(RSS).**

Then the procedure was repeated with the second transmission error force vector of magnitude twice unity and again normalized by dividing each RSS magnitude by the maximum RSS magnitude. While the sizes of the ellipses in the second analysis are greater in size than the first ones, their normalized sizes, in red, show the exact same trends. Even if the transmission error force magnitudes are unknown, this strategy is still useful for selecting idler gear parameters such as number of teeth and tooth thickness.

It is straightforward to see how the sum of the fundamental frequency force vectors may be minimized, but what about the higher harmonics? By reducing the transmission error force ellipse in the manner discussed, the odd harmonics will be minimized, but the even harmonics will be maximized. In the same way, the problem can be reformulated to minimize

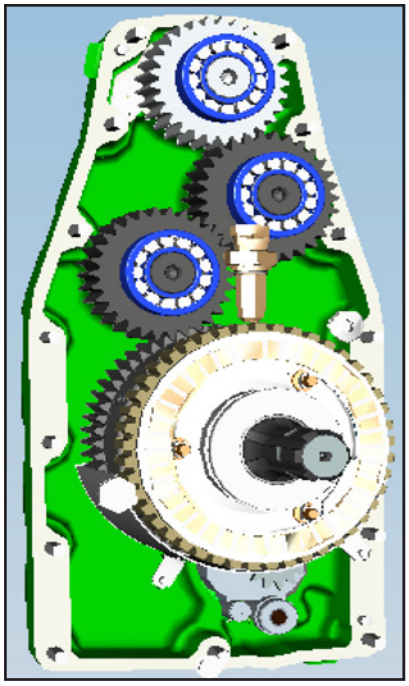

Figure 13 Front PTO gearbox with two idlers; the input is at the top (CCW rotation), then gears 2 and 3 and the output at the bottom.

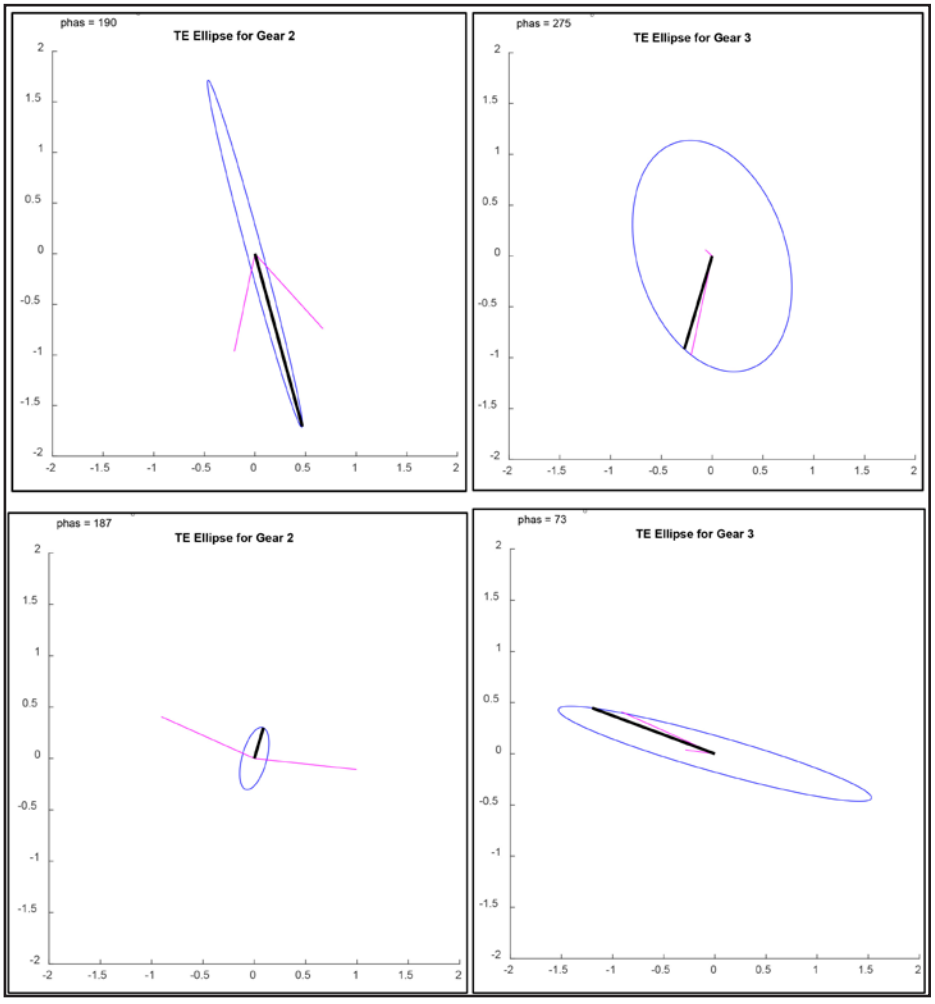

Figure 14 Front PTO transmission error force ellipses for the two idlers for forward (above) and reverse (below) input speed directions.

the even harmonic force ellipse for a challenging gear noise that is primarily second harmonic in nature. Because our gear tooth modifications and microgeometry tolerancing are mostly for the benefit of the fundamental harmonic, this is best controlled. Higher harmonics are of less predictable control. Why the even harmonics are maximized when the odd harmonics are minimized is shown in Appendix B.

Front PTO Gearbox

Early in the development cycle a front PTO gearbox suffered from gear whine. Power is transmitted through three meshes using two idlers (Fig. 13). This gave the authors an opportunity to apply the phasing concept. A quick analysis indicated that the TE force ellipses might be reduced by running the gears backwards by reversing the input shaft direction (Fig. 14), not as a solution, but to give credibility to the phasing concept and to get buy-in from design. Phasing analysis suggested that the total RSS for the reverse input direction would be about 3 dB less than the forward direction. The gearbox was tested by simply reversing the input direction and the sound pressure level indeed reduced about 3 dB. We now had their attention!

The maximum noise contribution was from the first harmonic, so the objective was to minimize the first harmonic by means of phasing, but keeping within certain constraints put forth before us by design. A *Matlab* program evaluated thousands of design permutations of idlers with different numbers of teeth, tooth thicknesses and positions. The proposed design reduced the first harmonic by 2 dB (Fig. 15). When tested, the overall noise was reduced 3 dB, but the second harmonic was now a problem due to a structural resonance (Fig. 16). Virtual and physical modal analyses determined that the second harmonic of mesh frequency excited the ninth mode of the housing. Stiffening the housing put this mode outside the operating range, providing a design that was 6 dB quieter (Fig. 17).

Caveats and Warnings

Earlier it was stated that the position of the idler affects the transmission error force ellipse and that the ellipse is aligned with the bisectors of the lines of action (assuming the transmission error forces are equal). While the size of the ellipse can be modified by changing the number of idler teeth and idler tooth thickness, the ellipse can only be reduced so much if the lines of action are perpendicular rather than parallel. In the best case, the lines of action are perfectly parallel, the forces are equal

and phased 180° and the odd harmonics are perfectly cancelled. But if the lines of action are perpendicular, no amount of phasing can reduce the ellipse size smaller than a circle of unit radius. The total potential of a design with perpendicular lines of action therefore is only 3 dB. Whether the lines of action tend to be more parallel or perpendicular depends on which side of the line of centers connecting the input and output gears that the idler is on, as indicated in Figure 18.

When selecting which side of the line of centers of the input and output gears to place the idler, the designer must consider the DC bearing forces on the idler. While there is potential to have the AC transmission error forces cancel by having parallel lines of action, this design results in the greatest DC bearing forces. And since bearing damage is proportional to force to the power of 3 or 3.33, the difference in using a parallel or perpendicular design can potentially affect bearing life by a factor of 3.

Up until this point, we have focused on the fundamental gear mesh frequency. The ellipse concept works for any harmonic of mesh frequency. The caveat is that even and odd harmonics cannot be perfectly canceled simultaneously. When

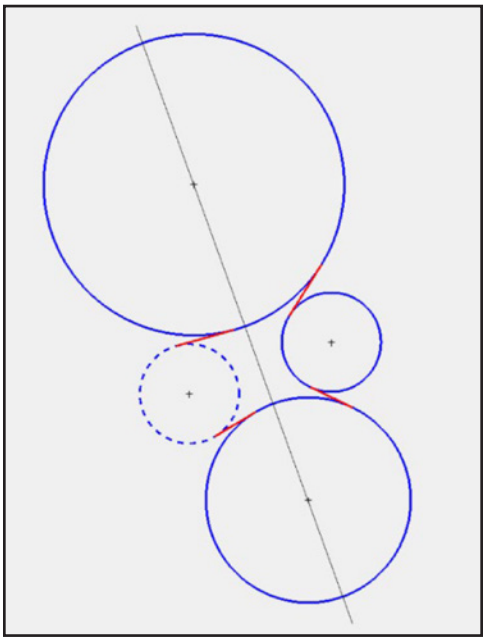

Figure 18 The lines of action for the idler on the right are roughly perpendicular and therefore provide limited opportunity for reducing the TE force ellipse; the left idler — shown as broken lines, however — has nearly parallel lines of action, providing the best opportunity for minimizing the size of the TE force ellipse.

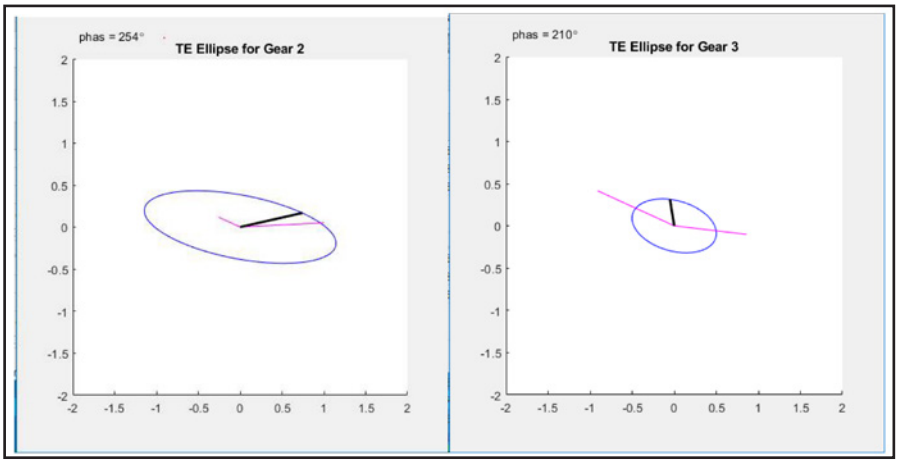

Figure 15 Front PTO transmission error force ellipses for the two idlers of the new design.

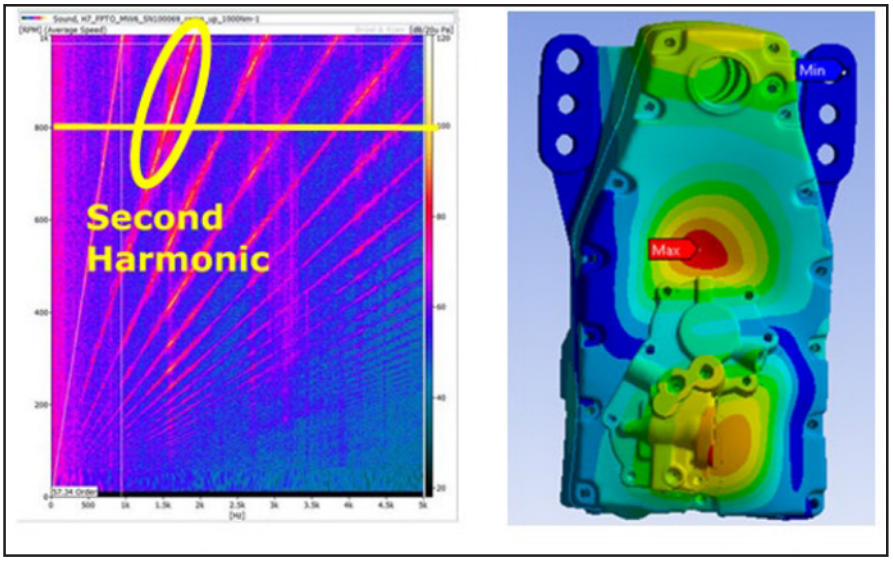

Figure 16 The waterfall plot highlights the problematic second harmonic of mesh frequency; the cause is the 9th mode shape shown at the right.

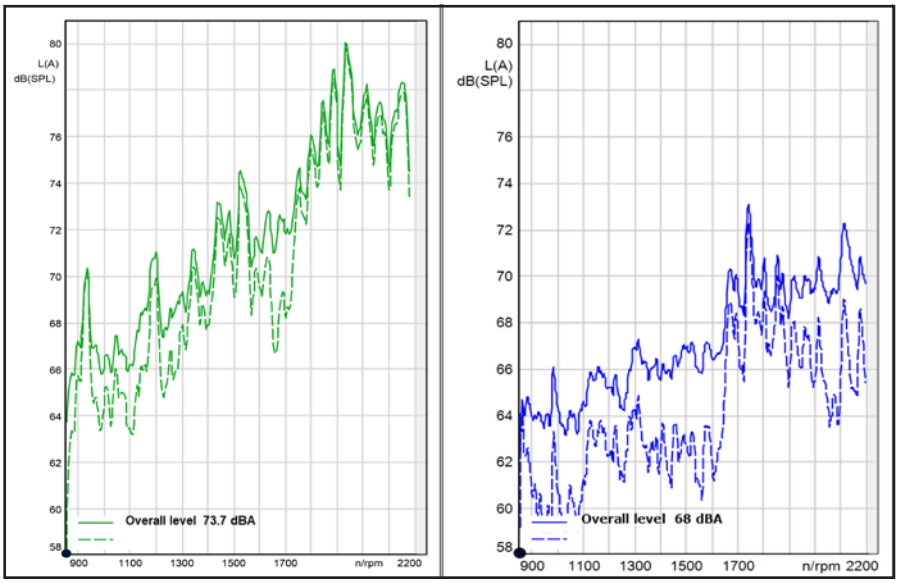

Figure 17 Overall and sum of the first four harmonics of sound pressure level for the original design on the left, and the final design on the right.

the odd harmonics are minimized, the even harmonics are maximized. Therefore, one must decide which harmonic is most important to minimize or do a weighted optimization. Because off-road gear tolerances do not well control the higher harmonics of transmission error one might opt to focus on the fundamental mesh frequency. This odd and even harmonic phenomenon is further described in Appendix B. For example, where the 18T idler of Figure 7 was one of the smallest ellipses, for the second harmonic, the 18T ellipse was one of the longest ellipses. The smallest ellipses for even harmonics are obtained when the phase shifts are about ¼ tooth (90°) (Fig. 19). This is consistent with the results described by Cheon and Brecher, et al. (Refs. 16–17).

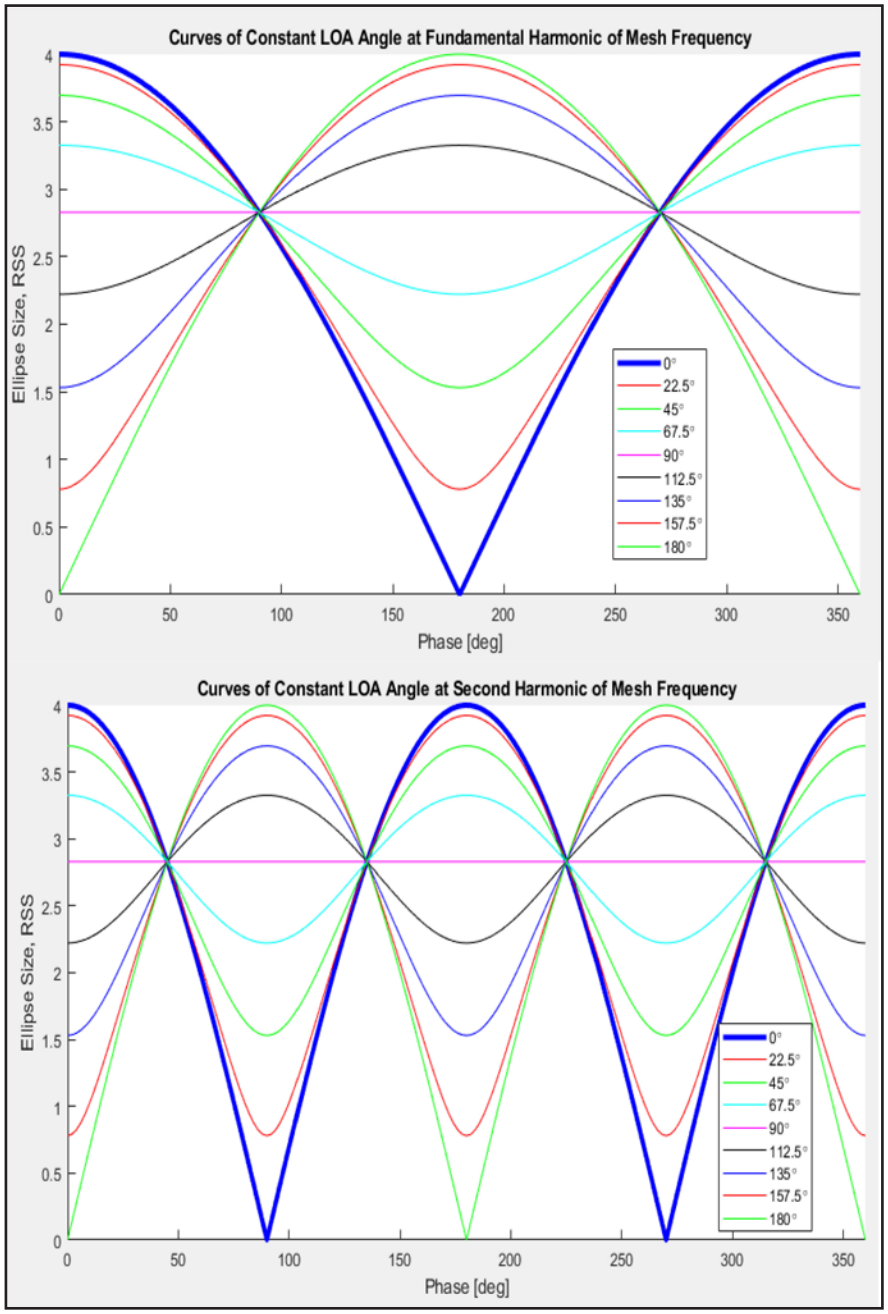

Figure 19 The size of ellipses generated for phase increasing from 0 to 360° with lines of action at various relative angles ($\theta_2 - \theta_1$) increasing from 0 to 180°. The upper plot is an analysis of the fundamental mesh frequency, and the lower plot is for the second harmonic; the bold blue curves denote lines of action that are parallel.

Quick Method for Verifying Whether Phase May Have Merit

One desires to reduce gear noise but does not wish to send the design team on a wild goose chase to redesign and procure parts to explore this theory. A simple way to determine whether this approach may be fruitful for a given application is to run the input in the opposite rotation direction. Quite often the transmission error force ellipses are quite different, and it gives one an opportunity to predict a change and then observe it. Not all gearboxes can be run backwards, but at John Deere the authors have made provision to run several gearboxes with reversed input shaft direction just for this purpose.

Summary

This work explains why some idler sets produce so much gear whine. While transmission error must be managed, as it is generally the greatest source of gear whine, there is another tool in the gear whine management toolbox the designer can make use of, phasing the meshes on the input and output sides of the idler. The TE forces on the two lines of action acting on the idler add together to make a resultant vector that sweeps out an ellipse as the gears are advanced one tooth. By adjusting the relative phase of these meshes, the transmission error force ellipse size and orientation can be manipulated. The three parameters that affect the ellipse are the number of teeth on the idler, idler tooth thickness and the orientations of the lines of action. The TE force ellipse is minimized when the phase is 180° for odd harmonics and 90° for even harmonics.

A case history of a PTO gearbox was provided that demonstrated how the gear whine was improved by making phase changes.

Design by means of phasing idlers offers no guarantees, but it does offer some possibilities. When tackling a tough gear noise problem for a specific mesh frequency harmonic, it is good to be aware that there is another design option to investigate.

The contents of this paper are protected by U.S. Patent 10,423,756 (Ref. 20).

For more information. Bob White consults as an NVH and Dynamics Engineer with White Noise, LLC and Pravin Pail is a Drivetrain NVH Engineer at John Deere. They may be contacted at: RobertWhite@WhiteNoiseUSA.com and patilpravin2@johndeere.com. They welcome your comments.

Recommendations for Future Work

The current work focused on reducing the transmission error force ellipse size for a sin-

gle family of harmonics (odd or even). Ideally all harmonics with their individual amplitudes and phases would be considered. This is easy enough to accommodate once a design is completed, but how does one guide designers early in the design? Perhaps many gear designs might be studied to determine typical relative amplitudes and phases and then apply them as rules of thumb.

Future work could also add the off line of action friction forces to the line of action transmission error force vectors, thereby generating force profiles that represent all the idler forces on the housing.

For more information. Bob White consults as an NVH and Dynamics Engineer with White Noise, LLC and Pravin Pail is a Drivetrain NVH Engineer at John Deere. They may be contacted at: *RobertWhite@WhiteNoiseUSA.com* and *patilpravin2@johndeere.com*. They welcome your comments.

Appendix A

This appendix develops the equation that computes the relative phase angle between the two meshes of an idler and the dimensions of the TE force ellipse. The phase equations are derived in the format of (Ref. 21) by evaluating angles around the idler from one mesh to the other. Parker and Lin use a different approach; calculating the phase of a planet gear in an epicyclic system by computing the linear distance from one pitch point to the other along the lines of action and around the base circle of the planet (Ref. 22).

Consider Figure A.1, which shows the mesh that drives the idler. Assume these gears are at the point half way between lowest and highest points of single tooth contact. The roll angles at those points are:

$$\lambda_{HPSTC}=\frac{C_1\sin\eta_1-\sqrt{r_{A1}^2-r_1^2}}{r_2}+\frac{2\pi}{z_2} \quad (A.1)$$

$$\lambda_{LPSTC}=\frac{\sqrt{r_{A2}^2-r_2^2}}{r_2}-\frac{2\pi}{z_2} \quad (A.2)$$

Therefore the midpoint roll angle for the input mesh is:

$$\lambda_1=\frac{C_1\sin\eta_1-\sqrt{r_{A1}^2-r_1^2}+\sqrt{r_{A2}^2-r_2^2}}{2r_2} \quad (A.3)$$

Where

λ_1 is the mean roll angle between LPSTC and HPSTC with gear 1;
C_1 is the length of the line of centers between the driving gear and the idler;
η_1 is the working pressure angle at the input mesh;
r_{Ai} is the addendum radius of gear I;
r_i is the base circle radius of gear I;
z_2 is the number of teeth on the idler gear.

Making use of Figure A.1 we see that:

$$\sigma_1^L=\Phi_1-\eta_1+\lambda_1 \quad (A.4)$$

Where

σ_1^L identifies the origin of involute (OI) of the left flank in contact with the driving gear;
Φ_1 describes the location of the driving (input) gear relative to the idler. Similarly, the mean roll angle between the LPSTC and HPSTC with gear 3 is:

$$\lambda_3=\frac{C_3\sin\eta_3-\sqrt{r_{A3}^2-r_3^2}+\sqrt{r_{A2}^2-r_2^2}}{2r_2} \quad (A.5)$$

Where

λ_3 is the mean roll angle between LPSTC and HPSTC with gear 3;
C_3 is the length of the line of centers between the idler and the driven gear;
η_3 is the working pressure angle at the output mesh.

Making use of Figure A.2 we see that:

$$\sigma_2^R=\Phi_3+\eta_3-\lambda_3-2\pi \quad (A.6)$$

Where

σ_2^R identifies the OI of the right flank in contact with the driven gear;
Φ_3 describes the location of the driven (output) gear

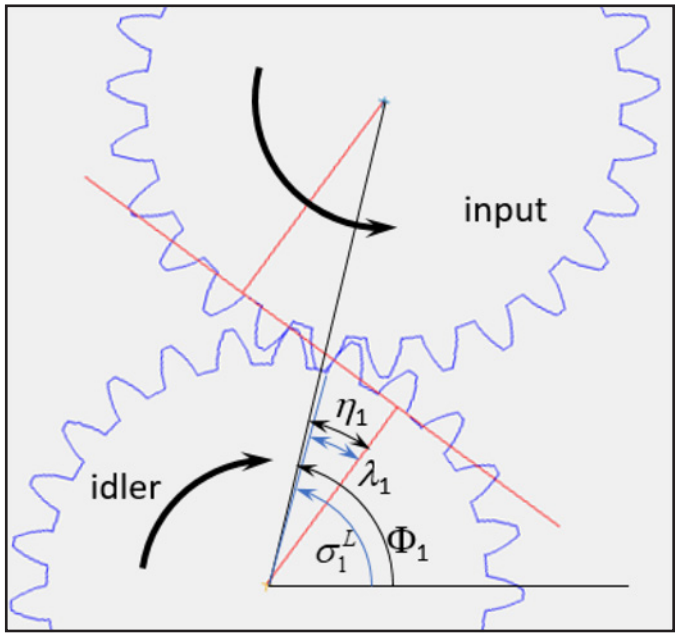

Figure A.1 Idler in mesh with input gear.

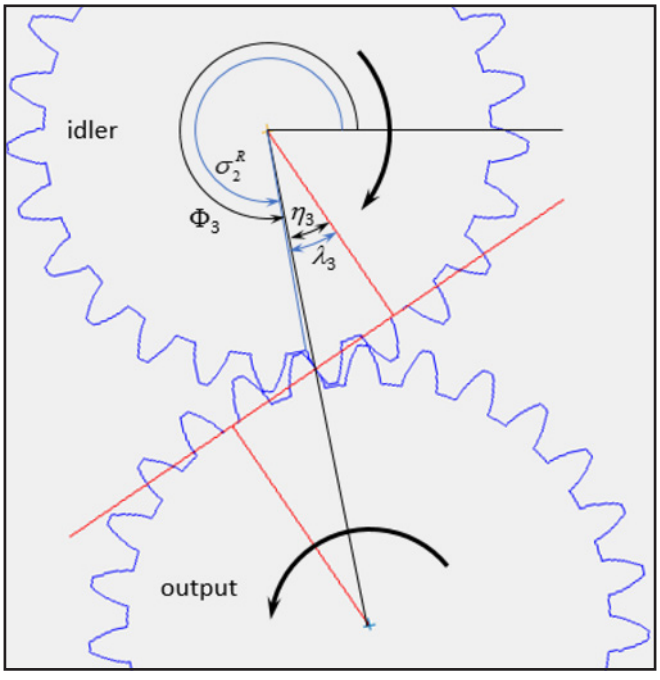

Figure A.2 Idler in mesh with output gear.

relative to the idler.

For idler rotation in the clockwise direction, 2π is subtracted so that σ_2^R is less than σ_1^L.

To go from the origin of involute on the right flank to the origin of involute on the left flank utilizes the tooth thickness.

$$\sigma_2^L = \sigma_2^R + 2\tan\varphi_t - 2\varphi_t + \frac{t_w \cos\varphi_t}{r_2} \tag{A.7}$$

Where

σ_2^L identifies the OI of the left flank of the tooth in contact with the driven gear;

φ_t is the transverse pressure angle of the hob;

t_w is the tooth thickness.

The sum of the last three terms of equation A.7 is the angle subtended by the tooth thickness at the base circle.

The number of teeth that are indexed to rotate the gear from σ_1^L is σ_2^L:

$$N = \frac{z_2}{2\pi}(\sigma_1^L - \sigma_2^L) \tag{A.8}$$

When N is an integer, both meshes occur simultaneously and are perfectly in phase. A phase shift in degrees is obtained by multiplying the mantissa of N by 360.

The ellipse is then generated as the sum of the transmission error force vectors at two lines of action.

$$\boldsymbol{F} = F_1 \cos(2\pi m f_1 t)\, e^{i\theta_1} + F_2 \cos\left(2\pi m f_1 \left(t - \frac{\varphi}{2\pi f_1}\right)\right) e^{i\theta_2} \tag{A.9}$$

Where

$\boldsymbol{F}$ is complex notation for the coordinates of the ellipse;

F_i is the magnitude of the TE force for line of action i;

f_1 is the fundamental mesh frequency;

t is the time sweeping over one mesh cycle, going from 0 to $1/f_1$;

m is the harmonic number;

θ_i is the angle of orientation of line of action i;

φ is the relative phase between the two idler meshes.

Except for Figure 12, all ellipses assume $F_1 = F_2 = 1$.

For the case where $F_1 = F_2$, the ellipse extremes are realized at $2\pi m f_1 t = m\varphi/2$ and $m\varphi/2 + \pi/2$. The major and minor axis lengths are twice the magnitude of F at these extremes. Inserting $2\pi m f_1 t = m\varphi/2$ into Eq. A.9 produces the axis dimension, a of Figure 9, oriented an angle $(\theta_1 + \theta_2)/2$. Putting $2\pi m f_1 t = m\varphi/2 + \pi/2$ into the same equation produces b, the length of the perpendicular axis.

$$a = 2\sqrt{2}\cos\left(\frac{m\varphi}{2}\right)\sqrt{1 + \cos(\theta_2 - \theta_1)} \tag{A.10}$$

$$b = 2\sqrt{2}\sin\left(\frac{m\varphi}{2}\right)\sqrt{1 - \cos(\theta_2 - \theta_1)} \tag{A.11}$$

And

$$\sqrt{a^2 + b^2} = 2\sqrt{2}\sqrt{1 + \cos(m\varphi)\cos(\theta_2 - \theta_1)} \tag{11.12}$$

Where

a is length of the axis of the ellipse at an angle of $(\theta_1 + \theta_2)/2$ (Fig. 9);

b is the length of the axis perpendicular to the first.

Appendix B

This appendix shows that phasing the transmission error forces by half a tooth (180° phase shift) tends to cancel the odd harmonics of mesh frequency but double the amplitudes at the even harmonics. The TE force amplitudes at all harmonics are assumed to be unity.

Given two parallel unit force vectors with fundamental frequency f_1 and phase shifted by $\varphi = \pi$, their resultant force is:

$$F = \cos(2\pi f_1 t) + \cos(2\pi f_1 t - \varphi) \tag{B.1}$$

The phase shift can be written as a time shift by:

$$\cos(2\pi f_1 t - \varphi) = \cos(2\pi f_1 (t - \tau)) \tag{B.2}$$

Where

$$\tau = \frac{\varphi}{2\pi f_1} = \frac{\pi}{2\pi f_1} = \frac{1}{2f_1} = \frac{T}{2}$$

T is the fundamental tooth pass period.

The 180° phase shift is tantamount to shifting the waveform half a period. But the transmission error forces are made up of several harmonics.

$$F = \sum_m \left[\cos(2\pi m f_1 t) + \cos\left(2\pi m f_1 \left(t - \frac{1}{2f_1}\right)\right)\right] \tag{B.3}$$

But

$$\begin{aligned}\cos\left(2\pi m f_1\left(t - \frac{1}{2f_1}\right)\right) &= \cos(2\pi m f_1 t)\cos(\pi m) + \sin(2\pi m f_1 t)\sin(\pi m) \\ &= \cos(2\pi m f_1 t)\cos(\pi m) \\ &= (-1)^m \cos(2\pi m f_1 t)\end{aligned} \tag{B.4}$$

Therefore

$$F = \sum_m \cos(2\pi m f_1 t) + (-1)^m \cos(2\pi m f_1 t) \tag{B.5}$$

The forces perfectly cancel when the two parallel transmission error force vectors are equal in magnitude and 180° out of phase and m = odd integers. However, the force sum is doubled for m = even integers. **PTE**

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Sulzer

SERVICE CENTERS KEEP U.S. MINING INDUSTRY MOVING

Mining companies invest huge sums into their equipment, which needs to deliver high output round the clock. Planned maintenance plays an important role in sustained reliability and many companies rely on it to deliver continued productivity. Sulzer's service centers in Gillette and Phoenix offer the overhaul of wheel motors as well as the recent introduction of exchange units, which minimize both downtime and investment for the customer.

Mineral mining continues to deliver important products, such as coal, copper, iron and gold, which are used in many aspects of our daily lives. Throughout the world, mining companies strive to improve efficiency and productivity, both of which are dependent on reliable machinery.

Heavy haul trucks are the workhorses of the open-cast mining industry. Capable of transporting several hundred tons of ore in a single load, these trucks are fundamental to the productivity, and profitability, of mining operations. However, keeping spare parts for these huge vehicles can involve a considerable investment. Each haul truck uses a pair of wheel motors, which weigh around 18 tons each and cost $1.3 million to replace.

Since the 1980s, Sulzer's Gillette Service Center in Wyoming has specialized in the maintenance and support of complex mining equipment. The Powder River Basin area around Gillette is the largest coal producing area of the U.S., home to around 40 percent of total domestic production. At the same time, the Phoenix Service Center in Arizona supports the copper mining business, which delivers over 50 percent of copper mined in the USA.

At both the Gillette and Phoenix sites, the company has invested in the skills and equipment necessary to complete the most complex wheel motor repairs, from rewinding motors to manufacturing obsolete or difficult-to-source replacement parts on its in-house CNC machines. Both facilities have also built a dedicated test stands for wheel motors, allowing refurbished units to undergo comprehensive quality checks, including temperature and vibration measurement, before being returned to service.

Repairing and reconditioning haul truck wheel motors is a significant undertaking. A basic overhaul requires around 400 hours of work by skilled technicians. If the unit has suffered a major failure, the work can extend to 800 hours. For Sulzer customers, however, a complex repair doesn't have to mean extended downtime. The service centers now run an exchange program for GEB25 and Y106 wheel motors, the two most common types used on Komatsu haul trucks.

When a wheel motor needs planned maintenance, a fully overhauled and tested unit will be delivered to the customer's site and exchanged in the field. That process takes just a few hours, allowing the customer to get the truck up and running with the minimum of downtime.

Back at the service center, every wheel motor goes through a complete strip down and inspection process. The center uses advanced computer-controlled metrology equipment to verify the condition of components and customers are involved in key decisions about whether to repair or replace critical parts.

The service centers keep an extensive inventory of components for wheel motors, generators and other haul truck systems. They use their knowledge of customers' fleets to forecast demand for wear-prone items such as bearings and gears, and to ensure they have access to hard-to-find parts or those with long lead times.

Decades of experience enable design improvements to be proposed and implemented to increase reliability, enhance serviceability and extend the operating life of refurbished units. The success of the exchange program for Komatsu trucks has created interest from other mine operators in the region, and Sulzer is currently investigating the feasibility of extending the service to other models.

"We have long been proud of our ability to tackle the most demanding technical challenges in mining equipment repair and overhaul," says Todd Colbrese, general manager at Sulzer Gillette Service Center. "With the exchange program, we can also make a big difference to our customers' primary business challenge: maximizing the availability and productivity of their assets." (*www.sulzer.com*)

Motion Industries

NAMES COOK EXECUTIVE VICE PRESIDENT AND CFO

Motion Industries, Inc. has promoted **Greg Cook** to Executive Vice President and Chief Financial Officer of Motion Industries, effective April 1, 2020.

Cook joined Motion Industries as senior vice president and CFO in November 2016 and quickly worked to improve the strategic effectiveness of the company's finance, accounting, tax, and treasury functions. Since joining Motion, he has also added responsibility for corporate strategy functions. In his expanded role, Cook will continue leading these current responsibilities, but will also now take on oversight of Motion's Information Technologies function.

"Since Greg has been with the company, we have been able to strengthen our bench in the finance and accounting departments, refine our strategic planning, and strengthen our balance sheet — improving our financial performance for GPC and our shareholders," said Motion Industries President, Randy Breaux. "Greg is a key member of the executive team, and I look forward to what the future holds under his continued leadership."

Cook has more than 29 years of experience in the manufacturing and distribution markets, and before starting with Motion Industries, spent 18 years with Shaw Industries, a Berkshire Hathaway company and leading North American manufacturer and distributor of flooring products. He began his professional career in public accounting at Arthur Andersen in Atlanta, Georgia. A CPA licensed in Georgia, Cook is involved in a number of industry and finance associations, including PTDA, AICPA, and ASCPA. He has a bachelor of science degree in accounting from Bob Jones University, where he graduated summa cum laude. Cook is also active in the local Birmingham community through his positions on the Samford University Brock School of Business Advisory Board and the Salvation Army Advisory Board. (*motionindustries.com*)

Bellofram Elastomeric Division

HIRES TWO REGIONAL SALES MANAGERS

Bellofram Elastomeric Division, which makes and markets products as Bellofram Silicones and Bellofram Diaphragm, is responding to recent growth with the hiring of two new regional sales managers. **Jared Krieg** and **Zachary Ridenour** began their new roles in the new year.

Krieg and Ridenour will promote Bellofram elastomer products to new businesses while continuing to advance the goals of current customers. "We have the highest-quality products in the market," said Rick Provenzano, national sales manager. "It will be Jared's and Zach's job to continue spreading our message of higher quality, peerless performance, and faster delivery."

Bellofram Elastomeric Division is in the midst of large gains and sustained customer growth, something Provenzano wanted to build on. The addition of Krieg and Ridenour is part of an investment in the future of the business and a strategy to further drive sales. "Jared and Zach both bring a tenacity, responsiveness, and knowledge base that complements our product offering and will strengthen customers throughout their regions," said Provenzano.

Krieg covers the Midwest region, including the Dakotas, Minnesota, Wisconsin, Illinois, Nebraska, Kansas, Missouri, Arkansas, Louisiana, Oklahoma, and Texas. Ridenour serves the Central region, reaching Michigan, Ohio, Indiana, Kentucky, Tennessee, Alabama, Mississippi, and Ontario, Canada. Both worked in their respective regions prior to joining Bellofram and will provide the company's signature responsive service, sound advice, and support to engineers and manufacturers throughout their territories.

Krieg has previously worked for Fastenal and Thyssenkrupp. Ridenour's previous experience includes stints with Grainger and Valspar. (*www.marshbellofram.com*)

Worldwide Electric

ACQUIRES LOUIS ALLIS

Worldwide Electric, LLC has acquired Louis Allis, a specialty motor company based outside of Birmingham, Alabama. Both companies take pride in their customer-centric approach and long history of motor expertise. The combination of the two companies establishes a single source for a full range of reliable standard off-the-shelf products, modified standard products, and full custom specialty products.

Louis Allis has been producing specialty motors for unique and demanding applications since 1901. Customers from around the world in the industrial, military, and municipal markets trust Louis Allis to provide new, factory recertified, and specialty motors up to 20,000 hp.

Since 1998, Worldwide Electric has been a leading developer, importer, and distributor of a broad portfolio of high performance industrial electric motors, gear reducers and motor controls. Headquartered in Rochester, NY, Worldwide Electric has 6 distribution centers throughout the US and is a proud member of the National Electrical Manufacturers Association (NEMA). Worldwide Electric Corp and Louis Allis will continue to operate as separate companies from their respective locations.

Worldwide Electric President and CEO James Taylor describes the acquisition as a significant win for the customers of both organizations. "Louis Allis and Worldwide Electric complement each other well. Louis Allis has a rich history of providing creative specialty motor solutions while Worldwide Electric has focused on providing readily available and high-quality motors, gear reducers and motor controls. Together, the companies will be able to meet all of our customers' industrial motor needs."

Louis Allis President Greg Peterson added, "Both organizations bring staff that are dedicated to putting the customer first. That dedication is the driving force in our success now and into the future." (*www.worldwideelectric.net*)

KISSsoft

LAUNCHES NEW WEBSITE

With the launch of its new website, KISSsoft focuses its strategy on digitizing the customer section and presenting a clearly structured and easy-to-use information and download platform. KISSsoft.com offers revised content, additional services, and functions, a clear structure as well as a slick new appearance. With eight language versions, KISSsoft strengthens its global presence and makes it easier for customers to communicate in their own language.

The "MyKISSsoft" customer portal integrated into the website lays the foundation for sustained use and puts the customer at the center of attention. Customers can now decide for themselves what kind of information they would like to receive and in which particular way. With the user-friendly and intuitive navigation, one can quickly achieve the desired aim in just a few clicks. KISSsoft presents the entire product and service portfolio in a clearly arranged form and reports on current topics such as engineering, software development, technical product descriptions, and much more. The website is equipped with search and filter options that allow quick access to product and training features.

(*www.kisssoft.com*)

Velodyne Lidar

ANNOUNCES SALES AGREEMENT WITH NAVYA

Velodyne Lidar, Inc. has announced a multi-year sales agreement with NAVYA, a leading company in autonomous driving systems. Since 2015, NAVYA has been using Velodyne lidar sensors in production for its autonomous shuttle fleet that provides mobility services to cities and private sites.

NAVYA plans to pursue the worldwide expansion of its shuttle with Velodyne's state-of-the-art sensors for precise

real-time localization and object detection. The NAVYA autonomous shuttle fleet offers effective first- and last-mile transportation solutions, with optimized navigation and safety features. The shuttles use advanced guidance and detection systems and are enhanced with deep learning technology.

"We are continuing our partnership with Velodyne Lidar because their technology enables us to place autonomous shuttles on the road today," said Jérôme Rigaud, COO, NAVYA. "Our successful five-year experience working with Velodyne's lidar solutions has proven that they provide a key component in our sensor kit needed to help move our fleet to the mass deployment stage."

"NAVYA is at the forefront of inventing and growing the autonomous shuttle business, providing an innovative, clean mobility solution," said Anand Gopalan, CEO, Velodyne Lidar. "Their driverless shuttles demonstrate how Velodyne lidar sensors provide robust data for safe, efficient navigation across urban centers, hospitals, universities, industrial sites and more." (*velodynelidar.com*)

Emerson

OPENS 2020 ASCO ENGINEERING SCHOLARSHIP PROGRAM

In its continuing commitment to the success of tomorrow's workforce, Emerson announces the application period is now open for its 2020 ASCO Engineering Scholarship Program for U.S. college students. The merit-based scholarships are awarded on the candidate's potential for leadership and for making a significant contribution to the engineering, instrumentation, systems, and automation professions. Recipients may also be eligible for an Emerson internship.

Emerson will award two U.S. engineering students a $5,000 scholarship each, host them at «The Amazing Packaging Race» at Pack Expo International, and grant their colleges' engineering departments $1,000 for research support.

"Challenges and opportunities in science and technology are greater, more rewarding, and more demanding than ever — for both students and industry," said Andy Duffy, vice president of sales for fluid control and pneumatics at Emerson. "At Emerson, we know there is no better investment to drive innovation than to support the learning of today's students — and tomorrow's workforce."

The scholarship recipients will be announced at Pack Expo International on November 11 in Chicago. There, Emerson will host the recipients at its Amazing Packaging Race, a fun and educational event in which teams of college students from around the country compete to gather points by completing tasks at specific Pack Expo booths.

The deadline to apply is May 1, 2020.

Emerson›s commitment to global support in STEM (science, technology, engineering, and math) education is deeply rooted in our heritage,» said Gordon Muir, president, industrial automation at Emerson›s Automation Solutions business. «With our ASCO Engineering Scholarships, we look to emphasize and celebrate STEM, highlighting the tremendous impact these skillsets have on the future workforce. Other corporate programs, from We Love STEM Days for elementary students to Post-Graduate Co-Op Programs, bring a multitude of opportunities to thousands of students around the world to explore STEM education — and to contribute, innovate and succeed in their careers, industry, and future.»

Over the past 12 years, $120,000 in ASCO engineering scholarships have helped to support the academic success of 24 students planning careers in engineering. An additional $24,000 in grants have assisted education research projects at the engineering departments of the colleges where the recipients were enrolled.

The scholarship is open to U.S. citizens and legal U.S. residents. Applicants must have completed their sophomore year in a bachelor's degree program or be enrolled in a graduate program at an accredited U.S. educational institution at the time of application. (*go.emersonautomation.com/asco-engineering-scholarship*)

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A Classic Computer Cameo

Siemens products and technologies seem to pop up in the strangest of places

Matthew Jaster, Senior Editor

In the classic film *Willy Wonka and the Chocolate Factory* (1971), a supercomputer is asked to determine the location of the main character's elusive golden tickets. The scene plays out like this:

"We're about to witness the greatest miracle of the machine age," says the overconfident computer engineer. "This machine will tell us the precise location of the three remaining golden tickets."

After entering the required data, the engineer patiently waits for the computer system to spit out the data. He then proceeds to read the results to his impatient supervisors.

"It says, 'I won't tell that would be cheating.'"

The scene — to this day — remains one of the funniest in the film as the make-believe world scrambled for a competitive advantage to find a way inside Willy Wonka's factory.

But did you know that the sarcastic computer system in the film is based on a real computer manufactured by Siemens in the 1960s?

According to the Siemens website, the company presented the world with the first mass-produced transistorized computer (The 2002 System) in 1957. The first unit was delivered two years later, to the Technical University in Aachen.

This was particularly noteworthy since the world market in data processing was almost entirely controlled by IBM in the United States during this time. The mass production of the Siemens 2002 System led to widespread use of data processing for a vast range of applications in Europe.

By 1965, Siemens five systems — the 4004/15, 25, 35, 45 and 55 — offered a series of increasingly powerful models. Upward compatibility from one system to the next was guaranteed. There was even two-way programming compatibility between the 4004/35, 4004/45 and 4004/55. All of which yielded a great deal of flexibility in customer use — an important competitive advantage.

Fast forward to 2020 and Siemens Digital Software Solutions offers a slew of technologies and design parameters for all the components found in the pages of this magazine — computer solutions for a new era of gear and motor design. Thankfully, these software solutions don't talk back like the one featured in the film:

"I'm now telling the computer that if it will tell me the correct answer, I will gladly share with it the grand prize."

He smiles, punches in some additional data and waits for another response.

"He says, 'What would a computer do with a lifetime supply of chocolate?'"

The Siemens 4004 was used in the film *Willy Wonka and the Chocolate Factory* (1971). Courtesy of Siemens.

"I'm now telling the computer *exactly* what he can do with a lifetime supply of chocolate ..." (*www.sw.siemens.com*) **PTE**

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